NASA High Performance Computing and Communications (HPCC) Program

Earth and Space Sciences (ESS) Project

Increasing Interoperability and Performance of Grand Challenge Applications in the Earth, Space, Life, and Microgravity Sciences

NASA Cooperative Agreement Notice (CAN)
Soliciting Proposals for
Research in High Performance Computing

CAN-00-OES-01
Issued September 18, 2000

Proposals due November 20, 2000

Released by:

Office of Earth Science

Office of Space Science

National Aeronautics and Space Administration
Washington, DC 20546-0001

(address not for receipt of proposals)

NASA HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance of Grand Challenge Applications in the Earth, Space, Life, and Microgravity Sciences

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CAN Overview

This NASA Cooperative Agreement Notice (CAN) is a solicitation by the Office of Earth Science and the Office of Space Science requesting proposals for scientific Grand Challenge Investigations. Technical coordination of this solicitation is provided by the High Performance Computing and Communications (HPCC) Earth and Space Sciences (ESS) Project, a cross-cutting information technology activity striving to enable the NASA science enterprises to prepare their scientific communities to meet increasing mission requirements more effectively and efficiently. Guided by the strategic plans of three NASA Enterprises (see URLs for strategic plans in Appendix F), ESS research increases the scientific community's capability to produce, analyze, and understand its science and mission data while reducing the investment in money and time required to do so.

The goal for selecting Investigations is to enable the science community to make production-ready high-performance computational applications that model, analyze, or interpret Earth, space, life, and microgravity science observational data. Successful Investigations are expected to develop a significant high-end computing application using accepted software engineering practices that:

- Addresses a significant element of one of the Earth, space, life or microgravity sciences associated with the NASA Enterprises' Strategic Plans, and
- Incorporates the use of NASA data to understand Earth, space, life, or microgravity science phenomena.

Proposed applications should incorporate established software engineering methods to:

- Foster reusability among software components and portability among high-end computing architectures,
- Reduce the time required to develop and modify application codes for research and production,
- Structure systems for better management of evolving codes, and
- Enable software exchange and interoperation between major research centers.

As a focused subset of this solicitation, the ESS Project is inviting teams to propose applications and frameworks that contribute to the development of an integrated Earth System Modeling Framework. Significant ESS support, described in the last three paragraphs of Appendix C, will be made available to Teams selected to participate in this framework activity.

NASA policy strongly encourages participation by the science community in education and public outreach activities with the goal of enhancing the formal education system and contributing to the broad public understanding of science. Therefore, proposers to this CAN are encouraged to include an Education/Public Outreach (E/PO) activity conforming to established guidelines as described in Appendix A.4 and A.5.

A schedule of advance payments to all selected Investigator Teams will be based on completion of milestones that are finalized during the negotiation phase of successful proposals and included in the cooperative agreements. Team milestones will include attaining application code interoperation and improvement goals described in Section 2. The ESS Project will provide winning Investigations with services focused on high-end computing, including access to large teraflops scale testbeds, code performance evaluation and optimization, visualization support, applications middleware development, and wide area network (WAN) research support.

This is the third round of ESS Grand Challenges. Teams are competed periodically to adjust the work of the Project and assure that it continues to be responsive to current developments in the Earth, space, life, and microgravity science communities. This round of Team selection is carried out through issuance of a CAN, followed by a full peer review, with final selection made by Enterprise science program management at NASA Headquarters. The objectives of this Round-3 CAN are significantly different from the Round-2 CAN [see Section 5 in Appendix E] due to alignment with the science objectives in the new Enterprise Strategic Plans and the recommendations made recently by the President's Information Technology Advisory Committee (PITAC).

Participation in this program is open to all categories of U.S. and non-U.S. organizations, including educational institutions, industry, nonprofit institutions, NASA Centers, and other Government agencies (subject to the guidelines in section 10). Historically Black Colleges and Universities (HBCUs), other minority educational institutions, and small businesses and organizations owned and controlled by socially and economically disadvantaged individuals or women are particularly encouraged to apply. As defined in the NASA Grant and Cooperative Agreement Handbook, all participating commercial organizations must propose at least 50% cost sharing, unless they show there is no commercial market or no expectation of recovery of development costs. Pursuant to regulation 1274.207(c)(7) of the Grant and Cooperative Agreement Handbook, recipients of NASA cooperative agreements may not be paid a profit. If the recipient is an educational institution or nonprofit organization, the provisions contained in Part 1260 of the Handbook apply; if the recipient is a commercial organization, the provisions in Part 1274 of the Handbook apply.

This CAN is being funded through the ESS Project. We expect approximately $18 million spread evenly over three years to be available (subject to appropriation availability) to fund the Grand Challenge Investigator cooperative agreements. However, funding for FY 2001 and subsequent years is dependent on the availability of funds. The decision as to which Grand Challenges to support will be based on the Evaluation Criteria found in Appendix G.7, and available funding. Depending upon the responses to this CAN and available resources, NASA contemplates selecting between eight and 10 Grand Challenge Investigator proposals to fund, but it reserves the right to enter into cooperative agreements with fewer than eight or more than 10 proposers and for amounts totaling less than the entire funding level, or to decide not to select any proposal to fund. Annual

funding levels are anticipated at between $300,000 and $1 million per award plus the negotiated values of optional milestones.

Only cooperative agreements will result from this CAN. A cooperative agreement is a financial assistance instrument used to stimulate or support activities for authorized public purposes and in which the Government participates substantially in the performance of the effort. The cooperative agreements resulting from this announcement are intended to continue for three years beginning in early FY 2001, pending continued program funding availability. The milestones, dates, and payment amounts will be negotiated with selected proposers prior to award.

The schedule for receipt and evaluation of proposals is given in Section 12. Appendix A describes the required and optional milestones for Investigator proposals. Appendix B discusses use of software frameworks for Earth, space, life, and microgravity science applications. Appendix C presents the concept of the Earth System Modeling Framework. Appendix D describes the computing testbeds for the use of Investigators selected by this CAN. Appendix E contains an overview of the ESS Round-3 activities of which this CAN is a major component. Appendix F contains World Wide Web References to additional project and program information that may be helpful in responding to this solicitation. Appendix G gives guidance for preparation of proposals and states the evaluation criteria. Appendix H contains information about the preproposal conference. Appendix I provides definitions of terms. Appendix J defines abbreviations and acronyms.

Identifier:	CAN-00-OES-01
Selection Official:	Associate Administrator Office of Earth Science
With concurrence by:	Associate Administrator Office of Space Science
Point of contact for technical questions regarding the solicitation:	Mr. Omar Spaulding NASA Headquarters, Code YF Washington, DC 20546-0001 Telephone: 202-358-0777 FAX: 202-358-2891 E-mail: ospauldi@hq.nasa.gov

This solicitation is available at http://www.earth.nasa.gov/nra/index.html

Your interest in participating in this CAN is appreciated.

Ghassem Asrar
Associate Administrator
Office of Earth Science

Edward J. Weiler
Associate Administrator
Office of Space Science

1. Introduction

This Cooperative Agreement Notice (CAN) is a solicitation by the Earth Science Enterprise and the Space Science Enterprise for scientific proposals that will enable continued progress toward solving Grand Challenge problems in the Earth, space, life, and microgravity sciences using scalable parallel computer systems. For purposes of this CAN, a *Grand Challenge* is defined as a fundamental problem in science or engineering with potentially broad economic, political, and/or scientific impact that may be advanced through the application of high-performance computing resources. This CAN broadens the scope of the challenge to bring high-performance scalable computing power to entire communities of NASA researchers. The HPCC Earth and Space Sciences (ESS) Project will coordinate the efforts selected by this CAN.

Grand Challenge Investigator proposals, described in Appendix G, are requested for cooperative research directed at the development, testing, and use of advanced high-performance applications codes using established software engineering methods to:

- Foster reusability among software components and portability among high-end computing architectures;
- Reduce the time required to develop and modify application codes for research and production;
- Structure systems for better management of evolving codes; and
- Enable software exchange and interoperation between major centers of research.

The Grand Challenge Investigator Teams selected through this CAN will be seeking to improve proposed specific application codes and expand their interoperability with other related codes within self-defined multidisciplinary scientific communities. In particular, development of an Earth System Modeling Framework (ESMF) will be a high priority for some of the selectees of this CAN. Customers of the technology to be developed by Investigations to be selected through this CAN include scientific research programs that require mature Grand Challenge codes for use in production and operational computing environments. Investigator Teams selected by this CAN will be required to make their improved application codes and associated framework openly available on the Web.

A separate, related competition for “plug-in” software applications codes to enrich the environment of the frameworks developed by the selected Teams will be run by ESS following the start of work by the Round-3 Grand Challenge Investigators. Investigators will be expected to assist the ESS Project in evaluating plug-in proposals and provide their frameworks to awardees. In addition, Grand Challenge Investigators may be required to work with the awardees of the plug-in competition. Conflict of interest rules will apply to the plug-in competition, i.e. Grand Challenge Investigators, as individuals, may not compete for plug-in awards, either as Principal Investigators or as members of Plug-in award teams.

Selected Investigator Teams will be provided access to significant computing resources and applications support, including a Teraflops Scalable Testbed and a Commodity Based Testbed, described in Appendix D. Teams selected will also be eligible to receive a range of related support in areas described in the next section.

2. Background

The ESS Project is part of the NASA High Performance Computing and Communications (HPCC) Program, a critical element of the Federal program in Computing, Information and Communications (CIC).

The overall goal of the ESS Project is to demonstrate the power of high-end and scalable cost-effective computing environments to further our understanding of and ability to predict the dynamic interaction of physical, chemical, and biological processes affecting the Earth, the solar-terrestrial environment, and the universe. Since its inception in 1992, ESS has pursued its goal through selection and support of two rounds of Grand Challenge Investigations. It is intended that this CAN will result in the selection of the third round of Investigations.

Most ESS Round-2 Investigations achieved the performance targets set out in the 1995 ESS Round-2 CAN, resulting in one to two orders of magnitude increase in performance of their codes. These Investigator codes have emerged as powerful tools for performing important Earth, space, life, and microgravity science work. These highly capable scalable codes have exposed new issues that are as important as performance: interoperability of high-performance codes, portability of applications among the variety of high-performance architectures, and management of the complexity of resulting coupled models. It has become evident that additional performance improvement, though necessary, is not sufficient to make a code useful for support of Earth, space, life, and microgravity science research and missions. The cost to adapt existing high-performance research codes to function with suites of other Earth, space, life, and microgravity science research or production codes for evaluation and eventual adoption and use may be prohibitively high. The reason is that code interoperability, which often exists among code components within specific research groups, rarely exists between these groups, and there are many such groups. In some cases, several Agencies such as NASA, NSF, DOE, and DOD fund multiple research groups within a modeling community, all researching advanced models, but these models lack the ability to interoperate. This situation is not a significant issue when the primary products of the research groups are research findings shared through scientific papers. However, with the emergence of powerful modeling codes as key tools of Earth, space, life, and microgravity science, preparation of these codes for ease of incorporation and use by their communities has become extremely important.

Four critical ESS Project level milestones listed below pace the three-year ESS Round-3 activity. They, along with their output metrics, are fundamental to the public purposes of this CAN. They are expanded to the 11 required Investigator Milestones in Appendix A.

"ESS 1-4" Baseline Grand Challenge model, assimilation, and data analysis codes
[January 2001]

"ESS 1-11" Demonstrate Grand Challenge codes interoperating within communities of related codes using prototype frameworks [March 2002]

"ESS 1-14" Demonstrate significant scientific improvement of Grand Challenge codes while conforming to interoperation standards [October 2002]

"ESS 1-17" Show sustainable customer use of Grand Challenge code components [October 2003]

3. Authority

This notice will result in cooperative agreements as defined in 31 U.S.C. 6305 (the Chiles Act) and is entered into pursuant to the authority of 42 U.S.C. 2451, et seq. (the Space Act).

4. Scope

4.1 Goals and Objectives of this CAN

A primary goal of ESS Round-3 is to achieve code interoperability through definition, adoption, and use of common software interfaces by broad communities of Earth, space, life, and microgravity science researchers. The objective of getting their codes to interoperate in common frameworks while simultaneously achieving high performance is viewed as a step to the next generation of production-ready software for many scientific communities. The communities to be supported under this CAN will be identified by the proposal selection process.

The following Round-3 Investigator objectives derive from this goal. They link the Investigators, the Testbed teams, and the NASA in-house computer and computational scientists:

(i) Prepare high-performance scalable parallel codes from Grand Challenge Investigations for broad use by Earth, space, life, and microgravity sciences research communities (see URLs for strategic plans in Appendix F);

(ii) Foster software interface agreements within relevant science communities enabling interoperation of software components;

(iii) Achieve code interoperation and high performance simultaneously;

(iv) Fill community priority needs for portable code components compatible with agreed-on software interfaces;

(v) Enable science communities to leverage code interoperation by testing, comparing, and using alternative code implementations; and

(vi) Facilitate spin-offs from Round-3 Investigations that benefit education, the public, or state and local governments.

Investigations are sought whose software products will be used by other groups, especially through an identifiable provider/customer relationship. Proposals should identify their customers, their deliverables, and the mechanism to be used to transfer the deliverables to the customers or into community assets.

4.2 NASA Provided Collaborative Assistance

The Grand Challenge Investigator Teams selected through this CAN are expected to serve as leading edge developers of high-performance applications codes and aggressive users of leading-edge scalable testbed systems and their software environments. They are expected to contribute significantly to the research synergism of the ESS Project. NASA's ESS Project, however, is expected to contribute the following collaborative assistance toward accomplishing the Grand Challenge Investigations:

- The applications support staff in the Teraflops Scalable Testbed provider organization assisting the Investigator Teams to achieve code improvement milestones. The acquisition of the Teraflops Scalable Testbed is described in Appendix D.
- System software developers and applications support staff for the Commodity Based Testbed evolving and supporting clusters of PCs using the Linux operating system operated as high-end computer systems for use and evaluation by Investigator Teams (Appendix D).
- GSFC Center-based software engineers supporting development of the Earth System Modeling Framework for interoperability of application codes.
- GSFC and JPL Center-based computer and computational scientists developing high-performance computational plug-in application codes in support of various frameworks represented by Round-3 Investigations.
- ESS evaluation staff (approach is described in Appendix E) assisting Investigators to characterize their application codes and carry out performance and scaling measurements on the Testbeds.
- GSFC and JPL Center-based staff developing applications middleware, high-end visualization, and mass storage technologies.
- ESS and NREN staff developing and applying wide area networking technologies.
- The Scientific Visualization Studio at GSFC developing visualization products for Investigator Teams via task orders.

Also, see the final paragraph of 5.1.2 for a discussion on NASA provided assistance for the Earth System Modeling Framework (ESMF). We do not, at this time, know the exact quantities and dates of availability of these items. These specifics will depend largely on

what individual Investigators propose and what is agreed to during negotiation of the selected proposals. Thus, it is important that offerors be specific about what types of support they are expecting from NASA, when that support is to be provided, and under what circumstances. In addition, providing some of these items are dependant upon on-going procurement actions. When these procurements are complete, we will have a more accurate picture of these specifics.

5. Software Development Strategy

5.1 Software Engineering Emphasis in Scientific Codes

Software engineering seeks to provide software solutions by design, having qualities including scalability, evolvability, dependability, usability, performance, and predictability of cost and schedule. Engineering documentation is integral for successful implementation of these qualities. Research in software engineering is ongoing. The best practices of a decade ago are often not accepted today.

ESS Round-3 Investigations are being sought that will engage science communities in the application of software engineering principles to the solution of their critical problems in high-end computing that are of national significance. These Investigations may involve legacy as well as newly developed codes. This work will be carried out on two fronts:

1) Applied Software Engineering within Investigator Teams: ESS requires the numerical packages developed in Round-3 to employ clear and specific software engineering methods. Desired results include proper structuring and documentation to support reuse, portability, and performance. An ambitious response would be to target Carnegie Mellon Maturity Model Level III; ESS expects that Teams will achieve Level II [see Capability Maturity Model for Software at http://www.sei.cmu.edu/cmm/cmms/cmms.html].

2) Community-based software frameworks: ESS strongly encourages Round-3 Teams to be engaged with other researchers within self-defined scientific communities in evolving mutually beneficial application frameworks. ESS encourages use of existing frameworks for faster development and a broader user base. If a new community framework is proposed, then this activity is expected to involve: joint community specification and construction of the framework with well defined interfaces, development of high-performance high-level model plug-in code components compatible with the framework, and interoperation as a community.

By addressing the issues of software engineering and code interoperation now, a better environment for application development and reuse will be fostered both within NASA and within the relevant research communities. A more detailed discussion of each of these two aspects follows.

5.1.1 Software Engineering within Investigator Teams

Software engineering is a critical aspect for the design and maintenance of robust software products. For example, developers of large-scale commercial applications commonly make use of phased approaches. This involves applying milestones to requirements, detailing designs, conducting design reviews and code walk-throughs, and completing the software incrementally. Many existing numerical modeling codes were designed long ago and have evolved without the benefit of modern software engineering techniques. A goal of the ESS Round-3 effort is to promote these important concepts to science projects that develop and make use of large ESS modeling codes. Some of the key concepts include:

- Documenting requirements for the application.
- Developing and implementing a strategy for a phased approach to software development for the full lifecycle of the model and linking the strategy to requirements.
- Developing and implementing an evaluation/audit process.
- Developing and implementing a software maintenance plan.
- Developing and implementing a validation plan.

ESS advocates principles of software engineering that have been part of past successful modeling projects:

- Use of modular code with well-defined, adaptive, and flexible interfaces.
- Use of common frameworks to standardize interfaces and allow interoperability.
- Use of commercial off the shelf (COTS) tools to promote development of highly scalable code that is both portable and high performing.
- Use of standard tool kits to construct user interfaces that are intuitive without the need for significant documentation.

Each proposal to the ESS Round-3 CAN will be required to have a software engineering plan that addresses the above issues. In particular, proposals should specify approaches to key points such as:

- Design elements that enable ease-of-maintenance and robust integration of experimental modules (maintenance and development may be geographically dispersed efforts). Flexibility, portability and performance are all important design goals.
- Plans for open source, software reuse, and interoperability with other community efforts.
- Plans for community engagement beyond delivery and receipt of comments.
- Plans to collaborate with the ESS Evaluation Team's efforts to instrument development codes.

5.1.2 Community Based Framework Engagement

Many of the above design goals involve community commitments and cannot be achieved unilaterally by single groups. As a result, groups will have to commit to using or building frameworks with their research community.

Frameworks are still an emerging technique, but they have demonstrated their value in managing large software projects spread over multiple locations. While first promoted in the context of reusability, they have become more popular as a mechanism to express open systems. A framework is defined as "a set of cooperating classes that makes up a reusable design for a specific class of software. A framework provides architectural guidance by partitioning the design into abstract classes and defining their responsibilities and collaborations. A developer customizes the framework to a particular application by subclassing and composing instances of framework classes." (See second Reference in annotated bibliography of Appendix B)

Interoperation of codes gives advantage beyond just adding more components to systems of coupled models. It opens the way for accelerating evolution of the coupled model systems. Research groups whose models do not interoperate with those of other groups have to supply all of their own model components. Advances from other groups can only be incorporated by changing their own model codes to incorporate the new 'foreign' features that are considered desirable. This situation could clearly be made more efficient. Agreement on certain software interfaces has been shown to facilitate sharing of model components allowing groups to run model components developed by other groups, stimulating comparison and adoption. Stable interface standards also open up the potential of tapping an even wider range of new intellectual capacity, notably algorithm developers who are not part of any of the major modeling groups, to contribute components that have broad impact.

A primary goal of the ESS Round-3 CAN is to achieve code interoperability through definition, adoption, and use of common software interfaces by communities of Earth, space, life, and microgravity science modelers allowing their codes to interoperate in common frameworks, and to simultaneously achieve high performance of individual codes operating in those frameworks. Appendix B provides a discussion of frameworks.

NASA is investing in the Round-3 Grand Challenge Investigations with the goal of having broad impact in the scientific communities. Investigations are sought whose code products will be used by other groups, especially through an identifiable provider/customer relationship. Proposals should identify their customers, their deliverables, and the mechanism to be used to transfer the deliverables to their customers or into community assets. All applications software developed under cooperative agreements must also be provided to the ESS Project in documented source form for a software releaseability review prior to publication via the World Wide Web.

In particular, ESS has set an objective in Round-3 of facilitating movement of a critical mass of the Earth system modeling community to a common modeling infrastructure (see Appendix C). The approach is to actively facilitate the joint definition of an Earth System Modeling Framework (ESMF) by this community and migration of their codes to this framework. This CAN will be responsive to proposals submitted in support of this objective. The ESMF effort will be a collaboration among the winning Round-3 Investigator Teams proposing participation in it and the ESS Project. In order for the ESMF activity to proceed, at least three high-quality

proposals that wish to participate must be selected. Participating ESMF Teams along with an ESS Project representative will be responsible for defining the framework. Teams will be responsible for implementing their applications within it. To facilitate this work, NASA will provide the services of a software engineering organization, termed the *ESMF Integrator*, to facilitate and support the development and implementation of the ESMF. The Headquarters Selection Official will constitute the ESMF Science Team to oversee this activity from among proposers who have expressed an interest in being a part of it (see Appendix C).

5.2 Application Improvement

Each proposing Team must identify in its proposal the code or codes that it will be improving and making interoperate with other codes in a framework. Several Team milestones will state the nature of the improvement and have a quantified metric stating the degree of improvement. The metric for each software improvement milestone must be in units of quality valued by the relevant science community or flight projects. A partial list of possible science metrics is given here, but only to stimulate the thought processes of those writing proposals since it is they, and not ESS, who must identify quality metrics important to relevant science or mission success:

- Throughput
- Resolution
- Volume of mission required products produced
- Physical fidelity
- Time to solution
- Relaxation of physical simplifying assumptions
- Number/variety of data sets used for initialization, validation, or assimilation
- Number of experiments conducted per unit time
- Number of community codes interoperating under a framework
- Data volume handled per unit time
- Performance in teraflops

The milestone achievement criteria for each metric must be stated and quantified. Milestone achievement criteria may be stated in absolute terms or as improvement over baseline. Further discussion of code improvement metrics and milestone achievement criteria is found in Appendix A.2.

6. Milestone Driven Agreements

6.1 Grand Challenge Investigator Teams

Candidate Grand Challenge application domains are found in the NASA Strategic Plans of the Earth and Space Science Enterprises and the Office of Life and Microgravity Sciences and Applications (see Appendix F). Many will require the integration of multiple advanced disciplinary models into single multidisciplinary applications.

Examples include coupled oceanic-atmospheric-biospheric interactions, 3D simulations of the chemically perturbed atmosphere, solid Earth modeling, solar flare modeling, and space weather modeling. Others are concerned with analysis and assimilation into models of massive data sets taken by spaceborne sensors in the areas of global warming and ozone depletion on Earth, planetary science, space weather, and astrophysics. Some of these problems have significant social and political implications; others address our place in the cosmos. The science requirements inherent in the Grand Challenge applications necessitate computing performance in the teraflops range.

Candidate ESS Investigator Teams may have members from any combination of academia, industry, NASA Centers, or other government agencies. Each Team must be led by a single Principal Investigator (PI) who is empowered to represent the Team in all administrative matters, including negotiations. Co-Investigators with accountable Team roles should be identified in the proposal. However, NASA will sign an agreement with only the PI's institution. It is the PI's responsibility to manage the Team, negotiate agreements among Team members, and arrange for disbursement of funds after payment. The PI is expected to spend, at a minimum, approximately 1/4 of his/her time on this project (research, management, and administration).

Each Team must propose to meet Required Investigator Milestones listed in Appendix A.1 and may propose one or two Optional Investigator Milestones (Appendix A.4). These milestones will be subject to further negotiation prior to a final cooperative agreement with the selected Investigators. ESS Testbeds will be provided to achieve these milestones (described in Appendix D). Note that the ESS Project mandates aggressive performance milestones, so this CAN targets scientists and scientific communities currently using parallel systems. Specifically, Investigator Teams must demonstrate experience in using scalable parallel processors, in measuring performance, and in performing software engineering. See Appendix A for details.

A "Science Team III," comprising the PIs selected for award under this CAN and a Project Scientist who will be elected from among the PIs, will be convened by the ESS Project and will operate during the three year award period. This group will augment the work of "Science Team II," which is composed of the ESS Grand Challenge Investigators selected under the 1995 NASA Cooperative Agreement Notice (CAN-21425/041). Information about the Science Team II Investigators and their work can be browsed at http://esdcd.gsfc.nasa.gov/ESS/investigators.html.

Science Team III (hereafter referred to as the "Science Team") will contribute to the evaluation of the Testbed architectures and the software environments that are part of the NASA HPCC Program. In particular, the Science Team will provide direct and frequent feedback to NASA and the Teraflops Scalable Testbed provider to highlight Testbed strengths and weaknesses and to streamline the process of identifying and correcting system deficiencies. It is expected that all PIs will participate in Science Team meetings, will be represented at computational techniques and evaluation workshops, and will contribute to Science Team reports. Each of these activities will occur at a maximum of

twice annually, and each Team should plan to send a representative. At the conclusion of Round-3, the Science Team members will jointly prepare findings and recommendations to NASA concerning future research directions in high-performance computing software and acquisitions of scalable computing systems.

6.2 Required Investigator Milestones

ESS will coordinate the Round-3 Investigator Teams through achievement of a schedule of negotiated milestones, each paid for in advance. These advance payments are made in a set order. Each signed cooperative agreement will contain at least 11 negotiated milestones as listed and described in Sections 1 through 3 of Appendix A. Each milestone will include an accomplishment or deliverable, its value in dollars, and its expected date of achievement. It is expected that the accomplishment or deliverable for many of the milestones will be Team specific. When a Team achieves a milestone, it documents the achievement and submits it to the ESS Project for validation, after which the team submits an invoice for advance payment of the next milestone.

6.3 Optional Investigator Milestones

There are a number of research activities taking place within ESS and the broader NASA HPCC Program that can benefit greatly by partnering with Grand Challenge Teams as technology customers. Descriptions of these activities are found in Appendix A.4. Teams proposing to Round-3 are asked to study these descriptions and propose one or two collaborative activities that would be of significant scientific value to the proposing Team. NASA and the Investigator Teams may negotiate up to two optional milestones into signed cooperative agreements.

7. Availability of Funds

This CAN is being funded through the ESS Project. We expect approximately $18 million spread evenly over three years to be available (subject to appropriation availability) for NASA to fund the Grand Challenge Investigator cooperative agreements. However, funding for FY 2001 and subsequent years is dependent on the availability of funds. The Government's obligation under the resulting cooperative agreements is contingent upon the availability of appropriated funds from which payment for cooperative agreement purposes can be made. No legal liability on the part of the Government for any payment may arise until funds are made available to the Contracting Officer for the resulting cooperative agreement and until the recipients receive notice of such availability, to be confirmed in writing by the Contracting Officer.

8. Cancellation of CAN

NASA reserves the right to make no awards under this CAN and, in the absence of program funding or for any other reason, to cancel this CAN by having a notice published in the Commerce Business Daily. NASA assumes no liability for canceling the CAN or for anyone's failure to receive actual notice of cancellation. Cancellation may be followed by issuance and synopsis of a revised CAN.

9. Withdrawal

The proposer may withdraw proposals at any time. Proposers shall notify NASA if another organization funds the proposal or if other changed circumstances dictate termination of evaluation. If an offeror submits the same proposal to organizations in addition to NASA, and one of those other organizations accepts it and funds it, the offeror must withdraw it from further consideration by NASA.

10. Foreign Participation (NASA FAR Supplement (NFS) 1835.016-70)

NASA seeks the broadest participation in response to broad agency announcements, including foreign proposals or proposals including foreign participation. NASA's policy is to conduct research with foreign entities on a cooperative, no-exchange-of-funds basis (see NASA Policy Directive (NPD) 1360.2 - Initiation and Development of International Cooperation in Space and Aeronautics Programs). NASA does not normally fund foreign research proposals or foreign research efforts that are part of U.S. research proposals. Rather, cooperative research efforts are implemented via international agreements between NASA and the sponsoring foreign agency or funding/sponsoring institution under which the parties agree to each bear the cost of discharging their respective responsibilities.

10.1 Additional Guidelines Applicable to Foreign Proposals and Proposals Including Foreign Participation (adapted from NFS 1852.28-41)

NASA welcomes proposals from outside the U.S. However, foreign entities are generally not eligible for funding from NASA. Therefore, unless otherwise noted, proposals from foreign entities should not include a cost plan unless the proposal involves collaboration with a U.S. institution, in which case a cost plan for only the participation of the U.S. entity must be included. Proposals from foreign entities and proposals from U.S. entities that include foreign participation must be endorsed by the respective government agency or funding/sponsoring institution in the country from which the foreign entity is proposing. Such endorsement should state that the proposal merits careful consideration by NASA, and if the proposal is selected, sufficient funds will be made available to undertake the activity as proposed.

All foreign proposals must be typewritten in English and comply with all other submission requirements stated in the CAN. All foreign proposals will undergo the same evaluation and selection process as those originating in the U.S. All proposals must be

received before the established closing date. Foreign sponsors may, in exceptional situations, forward a proposal without endorsement if the endorsement is not possible before the announced closing date. In such cases, the NASA sponsoring office should be advised when a decision on endorsement can be expected.

Successful and unsuccessful foreign entities will be contacted directly by the NASA sponsoring office. Copies of these letters will be sent to the sponsoring government agency. Should a foreign proposal or a U.S. proposal with foreign participation be selected, NASA's Office of External Relations will arrange with the foreign sponsor for the proposed participation on a no-exchange-of-funds basis, in which NASA and the sponsoring government agency will each bear the cost of discharging their respective responsibilities.

Depending on the nature and extent of the proposed cooperation, these arrangements may entail:

(i) An exchange of letters between NASA and the foreign sponsor; or
(ii) A formal Agency-to-Agency Memorandum of Understanding (MOU).

11. Small Business and Minority Institution Participation

Small business, small disadvantaged business, and women-owned small business concerns, as well as historically black colleges and universities (HBCUs) and other minority institutions are encouraged to participate in this CAN.

12. Schedule

The schedule for the review and selection of HPCC/ESS CAN proposals is as follows:

September 18, 2000	Release of the CAN	
October 2, 2000	Preproposal Conference	14 days after release
October 18, 2000	Letter of Intent to Submit Proposal due	30 days after release
November 20, 2000	Proposals due	60 days after release
February 5, 2001	Announcement of selections for negotiation	140 days after release
April 6, 2001	Announcement of award (target date)	200 days after release
April 26, 2001	Cooperative agreements signed	220 days after release

APPENDIX A
Required Milestones and Optional Milestones

A.1 Required Investigator Milestones

Section 6.2 introduced the required Investigator milestones and explained that they are to be paid for through a schedule of advance payments in a set order. This appendix lists these milestones, describes them, and shows the format for Teams to propose them. Each signed cooperative agreement will contain at least the 11 required milestones. Each milestone will consist of an accomplishment or deliverable, its value in dollars, and its expected date of achievement. Some milestones also need quantified metrics. Since each Team is unique, it is expected that the exact accomplishment or deliverable for many of the milestones will be Team specific. The exact wording and value of each Team specific milestone will be finalized by negotiation. When negotiations are completed the proposal is updated to be consistent with the result of negotiations, and the cooperative agreement [see sample at http://esdcd.gsfc.nasa.gov/ESS/CAN2000/CAN.html] is executed. The updated proposal is an attachment to the cooperative agreement and thus is necessary for its award. Immediately after its cooperative agreement is signed, each Team may invoice for the advance payment associated with its first milestone. When the Team achieves that milestone, it documents the achievement and submits it to the ESS Project for validation by the In-house Team. When ESS management determines that the milestone has been achieved, the PI's institution may then submit an invoice for the advance payment associated with the next milestone. This is the only way that funds are authorized for payment to a Team, and milestone payments will not be made out of order. This process continues until all payments are made and all milestones are achieved, or until a milestone is failed. (See Appendix A.6 for clarification.) This CAN will not result in award of a cost-reimbursable arrangement. Figure-1 shows the 11 milestones that prospective Round-3 Teams must propose.

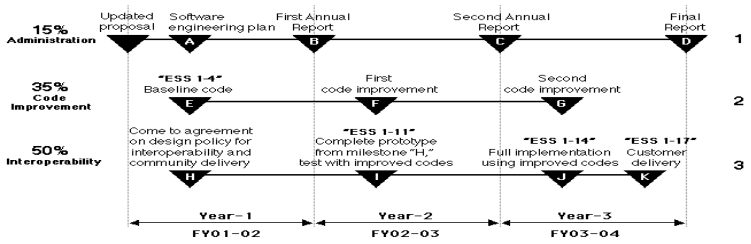

Figure-1: Each proposal must include these 11 milestones.
References to "ESS 1-X" are ESS Project Milestones defined in Section 2.

The 11 milestones in Figure-1 are grouped by line into three categories. Ideally, the payments in each category should match the percentages shown at the left margin.

The first set of milestones is administrative in nature:

A) Software engineering plan completed: validates that a suitable software engineering infrastructure exists within the Investigator Team necessary to carry out the proposed large scale, multi-code, and possibly multi-site, software development effort. It is the responsibility of the proposer to identify the software engineering needs of their Team and the means for implementation; a general discussion of these issues is found in Section 5.1.

B) First Annual Report delivered: as a Web page following a format template provided in the sample Cooperative Agreement. See examples of annual reports from ESS Round-2 Investigators at: http://esdcd.gsfc.nasa.gov/ESS/annual.reports/ess98/ess98.html.

C) Second Annual Report delivered: as above.

D) Final Report delivered: as a Web page following a format template provided in the sample Cooperative Agreement.

The second set of milestones focuses on code improvement: The metric for the baseline and the code improvements will be science related as discussed in Section 5.2. Appendix A.2 explains the possible need for an additional performance metric.

E) Code baseline completed: Teams establish the current baseline performance of the code or codes identified in the proposal to be improved on the ESS Teraflops Scalable Testbed. Improvements to be met in milestones F and G are negotiated relative to this baseline. Documented code developed to achieve this milestone is placed on the Web.

F) First code improvement completed: This milestone sets an intermediate level of code improvement over the baseline. Documented code developed to achieve this milestone is placed on the Web.

G) Second code improvement completed: This milestone sets the final level of code improvement over the baseline. Documented code developed to achieve this milestone is placed on the Web.

The third set of milestones focuses on software interoperation:
The relative cost of milestones H, I, and J compared to the others will depend on whether a Team constructs a new framework or uses an existing one. Frameworks need not be the only method to achieve these goals and milestones.

H) Design policy for interoperability and community delivery agreed on: Teams must either identify an existing framework or propose the creation of a new community framework. In both cases, they must show broad community support and commitment. They will deliver public definitions of the class libraries and interfaces (via the Web) with sufficient clarity that developers outside their Team can make productive use of

them and add new functionality. In the case of a new framework such as the Earth System Modeling Framework (ESMF) the broader community collaboration is clearly more challenging.

I) Interoperability prototype from milestone "H" tested with improved codes: A prototype framework is constructed with continuous community involvement. The ESMF integrator facilitates this for participating ESMF Teams. Existing applications are integrated into the framework, validated and their performance is evaluated. Community participation should be encouraged, with strong warnings as to the experimental nature of the prototype. All source code must be posted to the Web.

J) Full interoperability demonstrated using improved codes: Teams will use their collective experience to produce the next generation of application codes and frameworks. The ESMF integrator facilitates this for participating ESMF Teams. The community should be able to use this release of the framework with far less risk of wholesale structural change. The framework source code must be posted to the Web.

K) Customer delivery accomplished: Interoperability is demonstrated by the incorporation of foreign components as well as use of the framework by developers outside the Teams. Portability of this framework is demonstrated by moving it to different architecture(s).

A.2 Metrics for Baseline and Code Improvement Milestones

The metric for each Round-3 milestone related to code improvement (milestones E, F, and G) must be in units of quality valued by the relevant science community or flight projects. A partial list of possible metrics is given in Section 5.2. The milestone achievement criteria for each of these metrics must be stated and quantified (see Figure-2). Milestone achievement criteria may be stated in absolute terms or as improvement over baseline.

Statement of milestone	**Science metric** *(in units of quality valued by the relevant science community or flight projects)* ... **Milestone achievement criteria** *(quantified in absolute terms or improvement over baseline)* ...
...	

Figure-2: Code improvement milestones must include a science metric with quantified milestone achievement criteria.

In Round-2, the milestones proved useful to the Teams in focusing their efforts, while shared milestones aligned the efforts of the Testbed vendor and the Teams. The resulting optimization support by the Testbed vendor was critical to the success of the Round-2 Investigators. The existence of several negotiated performance milestones for each Investigator Team that set quantified performance expectations for all parties was viewed as an extremely powerful positive pressure by those involved. It empowered the Testbed vendor's applications support staff to formulate their technical approach in concert with the technical staff of each Investigator Team, who had the same goal. ESS plans to make available an equivalent approach in Round-3.

Even though the milestone achievement criteria of Round-3 Investigator Teams will be in units of quality valued by the science community, for Teams to receive substantive assistance from the applications support team provided by the Teraflops Scalable Testbed provider, the metrics for software improvement milestones must also be expressed in terms of performance. A partial list of possible performance metrics is given here:

- Throughput
- Volume of mission required products produced
- Time to solution
- Number of experiments conducted per unit time
- Data volume handled per unit time
- Performance in teraflops

Therefore, if the science metric for milestones E, F, and G is not quantified in terms of performance, proposals are asked to include an additional comparable performance metric with quantified milestone achievement criteria as shown in Figure-3. The milestone achievement criteria for each metric must be stated and quantified. Milestone achievement criteria may be stated in absolute terms, or as improvement over baseline. Figure-4 shows an example.

Statement of milestone ...	**Science metric** *(in units of quality valued by the relevant science community or flight projects)* ... ***Milestone achievement criteria*** *(quantified in absolute terms or improvement over baseline)* ...	**Comparable performance metric** *(only needed if the science metric is not expressed in terms of performance)* ... ***Milestone achievement criteria*** *(quantified in absolute terms or improvement over baseline)* ...

Figure-3: Code improvement milestones also need a comparable performance metric with quantified milestone achievement criteria if the science metric is not quantified in terms of performance.

Statement of milestone – F	**Science metric** *(in units of quality valued by the relevant science community or flight projects)* Resolution of simulation in meters ***Milestone achievement criteria*** *(quantified in absolute terms or improvement over baseline)* 5x	**Comparable performance metric** *(only needed if the science metric is not expressed in terms of performance)* Time to solution ***Milestone achievement criteria*** *(quantified in absolute terms or improvement over baseline)* Same time to solution as baseline
Improve MUDSLIDE3D resolution by 5x over baseline with same time to solution.		

Figure-4: Example of improvement milestone F with a science metric (not quantified in terms of performance) and a comparable performance metric (with quantified achievement criteria).

A.3 Required Investigator Milestones as would appear in proposal

Proposals must include a list of proposed milestones in a format similar to that shown below. The list should include the 11 Required Investigator Milestones as described in Section A.1.

Milestone	**Expected completion date**	**Value**
A) Software engineering plan completed Example: Deliver software engineering plan describing software engineering infrastructure within the Investigator Team. *[This is an update of the software engineering plan in the proposal responding to issues raised during negotiations.]*	<date>	<$>
E) Code baseline completed *Baseline <name of code or codes> using <state quantified science metric> <and state additional quantified performance metric if needed>. Provide code scaling curves. Post documented version of code used to achieve this milestone on the Web.*	Jan. 2001	<$>

Example: Baseline MUDSLIDE3D at maximum resolution on ESS Testbed for Mt. St. Helens event demonstrating at least 15% of peak machine performance. Provide code scaling curves demonstrating at least P/2 scaling to 256 processors; deliver documented source code via the Web. Deliver specification of the physical problem being simulated.

H) Design policy for interoperability and community delivery agreed on <date> <$>

Deliver agreement on definition for <identify framework> with <identify community members> and publish on the Web.

Example: Declare that existing QUAGMIRE Framework will be used to implement MUDSLIDE3D++. <Specify working relationship with QUAGMIRE team.> <Specify friendly users outside of MUDSLIDE3D++ and QUAGMIRE teams who will stress test and provide feedback for design.>

Example: Define and deliver document for new QUICKSAND2 Framework for MUDSLIDE3D++ to be developed for Milestone I. <Identify community members who will use the framework and mechanism for feedback to the developers.>

B) First Annual Report delivered Aug. 2001 <$>

Example: Submit FY01 Annual Report to ESS via Web.

F) First code improvement completed <date> <$>

Improve <name of code or codes> to <state milestone achievement criteria in terms of quantified science metric> <and state additional milestone achievement criteria in terms of quantified performance metric if needed>. Provide code scaling curves. Deliver documented version of code used to achieve this milestone on the Web.

Example: Improve MUDSLIDE3D++ resolution by 5x over baseline with same time to solution. Provide code scaling curves and deliver documented source code via the Web.

I) Interoperability prototype from milestone "H" tested with improved codes Mar. 2002 <$>

Implement and test improved version of <name of code or codes> with prototype of <identify framework>. Deliver framework source code via the Web.

Example: Demonstrate improved MUDSLIDE3D++ in QUICKSAND Framework using ROCK2D subgrid physics.

Deliver documented QUICKSAND Framework source code via the Web.

C) Second Annual Report delivered — Aug. 2002 <$>

Example: Submit FY02 Annual Report to ESS via Web. *[Include achievements from use of the released code by community.]*

G) Second code improvement completed — <date> <$>

Improve <name of code or codes> to <state milestone achievement criteria in terms of quantified science metric> <and state additional milestone achievement criteria in terms of quantified performance metric if needed>. Provide code scaling curves. Deliver documented version of code used to achieve this milestone on the Web.

Example: Improve MUDSLIDE3D++ resolution by 15x over baseline with same time to solution. Provide code scaling curves and deliver documented source code via the Web.

J) Full interoperability demonstrated using improved codes — Oct. 2002 <$>

Implement improved version of <name of code or codes> with improved version of <identify framework>. Deliver framework source code via the Web.

Example: Demonstrate full interoperability of MUDSLIDE3D++, ROCK2D, MUCK7, and FELLDOWN within QUICKSAND2 Framework. Deliver documented QUICKSAND2 Framework source code via the Web.

K) Customer delivery accomplished — Oct. 2003 <$>

Achieve sustainable customer use of <name of code or codes>.

Example: Port the QUICKSAND2 Framework to a different architecture than the Teraflops Scalable Testbed within 2 work weeks and demonstrate its operation. Deliver the QUICKSAND2 Framework and components to geology groups at university x, y and z.

D) Final Report delivered — <date> <$>

Example: Submit Final Report to ESS via the Web.

A.4 Optional Investigator Milestones

This appendix describes research areas where Teams may propose work for optional milestones in their Cooperative Agreements. Topics in the first area (items a-d) lead to joint collaborations between Grand Challenge Teams and technology development groups at GSFC and JPL where the Grand Challenge Teams become technology customers. Topics in the second area (items e-f) encourage use of clusters of inexpensive PCs. Topics in the third area (items g-i) assist spin-offs of ESS technologies. Teams proposing to Round-3 are asked to study the descriptions provided below, including referenced Web sites, and to propose one or two collaborative activities that would lead to valuable outcome. In addition to the statement of the milestone, each optional milestone needs a dollar value and a due date. These optional milestones are not mandatory, but it is hoped that each signed cooperative agreement contains one or two optional milestones with 10% to 15% of the total value of the agreement. In the event that a proposal is selected for negotiations, proposed optional milestones will undergo an additional evaluation for implementability.

To encourage joint collaborations – The Center-based portions of the ESS Project at GSFC and JPL reside within research and production computing organizations that develop new technologies and support Earth, space, life, and microgravity science. To help direct their research investments, these organizations wish to identify and carry out joint research projects with Grand Challenge Teams as technology customers. This Round-3 CAN is one mechanism to identify joint projects to be coordinated by negotiation of paid milestones with Teams. The complementary Center-based group at GSFC, JPL, or ARC would have the same milestone. The proposed milestone should be described in enough detail to enable the ESS groups to understand the proposed goal, assess the benefits to their work, estimate their required resources, and evaluate the appropriateness of the completion date. Proposers selected for negotiations will engage in a dialogue with the ESS group toward the mutual agreement of optional milestones in signed cooperative agreements.

a) Parallel Adaptive Mesh Refinement package augmentation

Adaptive mesh refinement (AMR) is an advanced numerical technique that enables Grand Challenge-scale applications to achieve spatial resolution beyond that possible with uniform grids. AMR devotes finite processor and memory resources to computational regions where they are most needed, thus making it possible to compute an accurate numerical solution with much less computing resources compared to global meshes. Development of parallel AMR algorithms and software tools is a relatively new research area compared to the work on serial computers. The Web page http://esdcd.gsfc.nasa.gov/ESS/amr.html describes two AMR packages being developed by ESS. Round-3 proposals are invited to propose to augment or use-as-is one or both of these packages to achieve a key milestone.

b) Visualization research

The Scientific Visualization Studio (SVS) at GSFC [http://svs.gsfc.nasa.gov/] is interested in collaborating with some Round-3 Teams. A list of SVS research topics is provided here to spark interest from proposing Investigators:

- Distributive visualization
- Collaborative visualization
- Virtual environments (direct manipulation, 3D, haptic, data sonification)
- Visualizing very large data (>100 gigabytes)
- High quality (non-interactive) visualization
- Visualization in real-time (during simulation)
- Parallel-based visualizations
- Visualization of unique data structures (e.g., adaptive mesh)
- Technology driven topics:
  Gigawalls, CAVEs
  Mini-CAVE (LAIR)
  HDTV
  low-end visualizations on PCs/Linux/laptops

The Parallel Volume Rendering group at JPL [http://alphabits.jpl.nasa.gov/ParVox/] is interested in collaboration with Round-3 Teams to develop high-performance visualization systems for large 5D scientific datasets. Specific research topics include:

- Visualization of various types of data sets, such as regular grid, irregular grid, curvilinear grid, and unstructured grid
- Customized classification algorithms
- Combination of hardware rendering and parallel software rendering
- Computation steering
- Remote and distributed visualization
- Effective Graphic User Interface

c) Mass storage research

Some Round-3 ESS Grand Challenges may be more constrained by their data intensive nature than their computing requirements. NCCS and the JPL Computing Center forecast that their principal applications will become increasingly data intensive, a trend we expect will be shared by Round-3 applications. These high-end computing centers must carry out path-breaking activities in mass storage because of the leading edge performance requirements of their customers. The ESS Teraflops Scalable Testbed (shared with several other high-end projects) and the Commodity Based Testbed, will be leading edge sites for mass storage research. There are nearly 80 terabytes of science data in the NCCS Mass Data Storage and Delivery System (MDSDS) [http://esdcd.gsfc.nasa.gov/SCB/NCCS-mass-storage.html] with network transfers approaching 0.5 terabytes per day using the UniTree Central File Manager software [http://www.unitree.com/products/prod_ucfm.html]. ESS conducts research on commodity-based mass storage servers [http://beowulf.gsfc.nasa.gov and http://parlweb.parl.clemson.edu/pvfs/]. Proposals of collaboration are invited in the following areas:

- Path-breaking MDSDS functionality expansion such as:
  - Distributed data movers - are they feasible as a way to ameliorate mass storage latency, can they improve concurrent data transfer performance?
  - Use of file subsetting or/and segmenting as a way to optimize extraction of data-of-interest in very large files.
- Commodity-based mass storage servers

d) Networking research

The HPCC NASA Research and Education Network (NREN) Project led by ARC is cooperating with ESS to support the development and prototyping of NREN/ESS networking research and applications. Projects proposed for a "Networking Research" optional Investigator milestone should push the envelope of distributed science computation and visualization over high-performance research and education networks (HPRENs). Such networking research activities as distributed "middleware" for security or multicast, or provision and measurement of end-to-end quality of service (QoS), at very high speeds over multiple HPRENs, would be especially interesting. The networks involved would be one or more of the NGI "JETnets" (NREN, NISN, Abilene, vBNS, ESnet, DREN) or the DARPA SuperNet networks (e.g., NTON, MONET, OnRamp). More information is available at:

NREN	http://www.nren.nasa.gov
NISN	http://www.nisn.nasa.gov/
Abilene	http://www.internet2.edu/abilene/
vBNS	http://www.vbns.net/
ESnet	http://www.es.net/
DREN	http://www.hpcmo.hpc.mil/Htdocs/DREN/
ATDnet	http://www.atd.net/
SuperNet	http://www.ngi-supernet.org/
NTON	http://www.ntonc.org/

New Next Generation Internets such as the DARPA-funded SuperNet testbeds and the Internet2-funded Abilene network currently are being deployed nationwide at 2.5 Gbps in each of one-to-eight optical wave division multiplex (WDM) channels. For the last four years GSFC has participated actively in the Advanced Technology Demonstration Network (ATDnet). DARPA has upgraded ATDnet to a SuperNet with 2.5-to-10 Gbps in eight-channel WDM networking elements from the Multiwavelength Optical Network (MONET) Consortium and has interconnected it at 2.5 Gbps to the other SuperNets. This enables Earth and Space Science Enterprise programs such as the Digital Earth, Teraflops Scalable Testbed, and Digital Sky to achieve end user data rates greater than 1 Gbps. However, network application users typically do not obtain such data rates because their applications are not "network tuned" or their host computers aren't using more modern network protocols. In Round-3, ESS will encourage Investigators to tune their applications to perform well over the available high-speed networks and to assist with research that improves either the network protocols or the software interfaces

between their application level programs through their host computer's operating system to their computer's network interfaces.

To encourage use of clusters of inexpensive PCs – In Round-3, ESS will encourage Investigator use of clusters of inexpensive PCs for Grand Challenge code development and performance runs, in particular the Linux-based approach [http://beowulf.gsfc.nasa.gov/]. ESS sees the *pile of PCs* approach to high-end computing as complementary to traditional proprietary vendor supplied high-end systems and expects that some, but not all, Round-3 applications can be modified to exploit this technology. Hence, ESS expects that PC clusters will supply a significant percentage of the computational resources for Agency research and mission support.

e) Installation of a PC cluster at an Investigator's home site

Several ESS Round-2 Investigator Teams installed Linux clusters and reported their benefits for training students, debugging scalable codes and providing inexpensive cycles for simulation and analysis. Round-3 Investigators may propose a milestone to install a local PC cluster (either Linux or NT). ESS will assist with specifying Linux systems but would not expect to contribute significant technical support for construction or operation. ESS will hold a tutorial/workshop to present approaches for achieving compatibility between Investigator Linux clusters and those at GSFC. Some report on usage and performance of the cluster must appear in a later Annual Report. The value of this milestone may be no more than $100,000.

f) Achievement of a code improvement milestone on a PC cluster

ESS needs comparative studies of the same code running on different architectures. Teams are encouraged to propose code improvement milestones F or G on a large Linux cluster and the Teraflops Scalable Testbed and to document this work with a comparative study. ESS has built several generations of increasingly more capable Linux systems at GSFC since 1994 [http://beowulf.gsfc.nasa.gov] and plans systems with 256 to 512 processors in Round 3 that will be available to Investigator Teams. Specifics of their size and characteristics will be influenced by negotiated Investigator milestones requiring their use.

To assist spin-offs of ESS technologies – ESS is interested in expanding the utility of the research software developed by Investigator Teams beyond their own research community by considering the needs of other research communities and of the educational and operational communities in the public and private sector.

g) Software tools

Investigator Teams may develop important software tools to support their Grand Challenge research. Some of these tools will have potential for broad applicability but lack an adequate degree of refinement, flexibility, or documentation to allow productive use by other groups. This option is provided to support adaptation for and adoption of software tools by communities beyond that of the developing scientific researchers.

h) Education and Public Outreach (E/PO)

NASA has goals to benefit the public such as improving science, mathematics, engineering, technology, and geography education, particularly at the pre-college level. Grand Challenge Teams may propose optional milestones supporting these goals towards *"Educational Excellence – We involve the educational community in our endeavors to inspire America's students, create learning opportunities, and enlighten inquisitive minds"* [http://education.nasa.gov/implan/exec.html].

The proposer should demonstrate its commitment to the E/PO effort and the active involvement of the PI and/or appropriate research team members in carrying out a meaningful, effective, credible, and appropriate E/PO activity, and that the proposed investment of resources will make a significant contribution towards meeting these purposes.

The following considerations will be applied to the determination of implementability of the proposed E/PO efforts in the event that the overall proposal is selected for negotiation:

- The quality, scope, and realism of the proposed E/PO activity including the adequacy, appropriateness, and realism of the proposed budget;

- The capabilities and commitment of the proposer and proposer's team to carry out the proposed E/PO activity;
- The establishment or continuation of effective partnerships with institutions and/or personnel in the fields of education and/or public outreach as the basis for and an integral element of the proposed E/PO activity; and
- The appropriateness of plans for evaluating the effectiveness and impact of the proposed E/PO activity.

For proposed efforts dealing with curriculum support products, standards-based educational materials should be developed which are aligned with and linked to nationally recognized and endorsed education reform efforts and/or reform efforts at the state or local level for the teaching of science, mathematics, engineering, technology, and geography. These standards-based products are expected to enhance the educational process, to address the development of innovative learning tools and strategies, and to empower and support the educator. Further information on National Education Standards can be found at http://spacelink.nasa.gov/Instructional.Materials/National.Education.Standards/. Proposers should detail how they specifically intend to comply with these directions in their response.

i) Broader technology transfer and access (applications)

Grand Challenge Teams may propose ways for making problem solving approaches, algorithms, modules, or data products resulting from their Investigations useful to operational entities in the public sector (such as state and local governments) or private industry by considering their requirements in routine operation. Applications may take the form of products or services and the associated necessary training and support, and may fall into the category of commercialization.

A.5 Optional Investigator Milestones as would appear in proposal

Proposals may include up to two optional milestones as described in Section 4 of Appendix A in a format similar to that shown below.

Milestone	Expected completion date	Value
a) Parallel Adaptive Mesh Refinement (AMR) package use or augmentation *[specific collaboration with GSFC or JPL to use or augment a Parallel Adaptive Mesh Refinement (AMR) package]* Example: Merge PARAMESH (Parallel Adaptive Mesh Refinement Package) into QUICKSAND2 Framework. Supply sample adaptive MUDSLIDE3D++ simulation with performance and scaling curves.	<date>	<$>

b) Visualization research <date> <$>
[specific collaboration with GSFC or JPL to use or augment visualization or parallel visualization capabilities]

Example: Incorporate Immersadesk drivers into WATCHITSLIDE modules of QUICKSAND2 Framework. Deliver demo for SC02 conference.

c) Mass storage research <date> <$>
[specific collaboration with NCCS at GSFC to develop augmented high-performance mass storage capabilities]

Example: Install a prototype UniTree remote distributed data mover system at Palisades University, controlled by the master UniTree storage management software at the NCCS. Work with the NCCS to deliver an assessment of the usability of this system in a testbed production environment, including measurements of performance and robustness.

Example: Work with the NCCS to evaluate a prototype of the UniTree storage management software that handles segments/subsets of files. Test the ability of the prototype to optimize the extraction of data-of-interest within very large files. Deliver an assessment of the usability of this system in a testbed production environment, including measurements of transparency to Investigator applications, performance, and robustness.

Example: Install [specific] parallel I/O package on Linux cluster at Palisades University. Deliver performance and scaling for SAR processing compared with MUDSLIDE3D++ simulations.

d) Networking research <date> <$>
[specific collaboration with NREN or Advanced Networking/GSFC to use or augment high-performance wide area networking capabilities]

Example: Using <specify Legion, Globus, etc.> capabilities in QUICKSAND2 Framework run MUDSLIDE3D++ distributed over computers at JPL and GSFC.

e) Installation of a PC cluster at an Investigator's home site <date> <$>
[Install and make operational at an Investigator site a PC cluster for code development and testing] [value constrained to $100K]

Example: Install 32-processor NT cluster at Palisades University. Demonstrate MUDSLIDE3D running on the cluster.

Example: Install a 16-node (32-processor) Linux cluster at Palisades University. The system characteristics will be 450

MHz Pentium-IIIs, 256 MB RAM, 13 GB IDE disks and channel bonded switched fast Ethernet, or better (depending on price/performance recommendations from ESS at the time of purchase). The system will be installed with a configuration that is consistent with the Linux clusters at GSFC as specified in the Beowulf administrator's tutorial given by ESS.

f) Achievement of a code improvement milestone on a Linux cluster <date> <$>
[Achieve either milestone F or G on the Teraflops Scalable Testbed and a Beowulf system to be provided by ESS - subject to agreement by ESS to provide the needed system. Provide a comparative analysis.]

Example: Demonstrate price/performance improvement of at least a factor of 9 for MUDSLIDE3D running on a Linux cluster compared to execution on the Teraflops Scalable Testbed.

Example: Port to a Linux cluster and evaluate the performance based on milestone F and G of MUDSLIDE3D without algorithmic modification. Work with the in-house Evaluation Team to identify system characteristics that enhance or impede the cost-effective use of cluster computing.

Example: Using the framework developed for QUICKSAND2, replace the communication intensive module MUCK7 with an approximation scheme AMUCK. Evaluate the impact on overall fidelity of QUICKSAND2 and its utility to its NASA mission compared to raw runtime and cost/performance of running on a cluster.

g) Software Tools <date> <$>
[approach to adapt software tools to become useful to a significant user community]

Example: Document and release via the Web large data set visualization software with support for adaptive meshes.

Example: Extend, document, and release via the Web library modules for the fast topological untangling method.

h) Education and Public Outreach <date> <$>
[approach to develop curriculum support products in science, mathematics, engineering, technology, and geography]

Example: Partner with a science museum and/or planetarium to utilize software tools and/or visualization capabilities developed through these investigations for purposes of public education.

Example: Work with Project <see possibilities at http://www.earth.nasa.gov/education/catalog/index.html> to develop modules to enable learning about the planetary radiation balance and the transport and transformation of energy that result in the observed and modeled temperature distributions.

i) Broader Technology Transfer and Access (Applications) <date> <$>
[approach to make problem solving approaches, algorithms, modules or data products coming out of Round-3 Investigations useful to public organizations such as state and local governments or private industry]

Example: Work with <specify project lead> at FEMA to provide a version of MUDLSIDE3D++ within QUICKSAND2 Framework that could be used for planning evacuations from a Mt. Rainier event. Insure that user interfaces are sufficient to support FEMA planners.

Example: Work with <specify project lead> in the Department of Civil Engineering to apply MUDSLIDE3D++ to problems of stability of concrete bridge footings in the Hood Canal Floating Bridge.

Example: Work with <project lead> in the State Department of Natural History to simulate evolution of La Brea Tar Pits using MUDLSIDE3D++.

A.6 Template schedule of milestones, due dates and advance payments

The template schedule of milestones in Table-1 brings together the information requested in sections A.1 through A.5 above. Offerors should complete the items in the template and provide them in chronological order by expected completion date as part of their proposal. Following negotiations, an updated schedule will be included in the signed cooperative agreements. Figure-1 in section A.1 helps to explain the milestones and their expected sequence of completion.

Table-1: Template schedule of milestones, due dates and advance payments

Mile-stone #	**Mile-stone label**	**Milestone Title <followed by statement of milestone>**	**Expected CompletionDate**	**Advance Payment Amount**
<#>	A	Software engineering plan completed <statement of milestone>	<date>	<$>
<#>	E	Code baseline completed <statement of milestone> including: - science metric, milestone achievement criteria - comparable performance metric, milestone achievement criteria (optional) - documented source code, scaling curves posted to Web	<date>	<$>
<#>	H	Design policy for interoperability and community delivery agreed on <statement of milestone> including: - design policy posted on Web	<date>	<$>
<#>	B	First Annual Report delivered <statement of milestone>	<date>	<$>
<#>	F	First code improvement completed <statement of milestone> including: - science metric, milestone achievement criteria - comparable performance metric, milestone achievement criteria (optional) - documented source code, scaling curves posted to Web	<date>	<$>
<#>	I	Interoperability prototype from Milestone "H" tested with improved codes <statement of milestone> including: - framework source code posted on Web	<date>	<$>
<#>	C	Second Annual Report delivered <statement of milestone>	<date>	<$>
<#>	G	Second code improvement completed <statement of milestone> including: - science metric, milestone achievement criteria - comparable performance metric, milestone achievement criteria (optional) - documented source code, scaling curves posted to Web	<date>	<$>
<#>	J	Full interoperability demonstrated using improved codes <statement of milestone> including: - framework source code posted on Web	<date>	<$>
<#>	K	Customer delivery accomplished <statement of milestone>	<date>	<$>
<#>	D	Final Report delivered <statement of milestone>	<date>	<$>
<#>	-	[title of optional milestone] <statement of milestone>	<date>	<$>

<#>	-	[title of optional milestone] <statement of milestone>	<date>	<$>

<#>: Chronological sequence number. The order of these milestones is negotiable, prior to award.
<date>: Expected milestone completion date, to be proposed by offeror and negotiated.
<$>: Cost to complete milestone, to be proposed by offeror and negotiated.

APPENDIX B
Frameworks for ESS Applications

There is a wealth of literature that can help Teams judge and/or build frameworks. Frameworks trace their early history to the GUI technologies built using Smalltalk. However, they now appear in many domains. The Taligent Introduction to Building Object Oriented Frameworks [1] provides four important guidelines:

- Derive frameworks from existing problems and solutions.
- Develop small, focused frameworks.
- Build frameworks using an iterative process driven by client participation and prototyping.
- Treat frameworks as products by providing documentation and support, and by planning for distribution and maintenance.

Ralph Johnson [2, 8] defines an object-oriented framework as having two essential parts:

- A reusable design expressed as a set of abstract classes.
- A description of how instances of those classes collaborate.

A framework is a set of prefabricated software building blocks that programmers can use, extend, or customize for specific computing solutions. With frameworks, software developers don't have to start from scratch each time they write an application. Frameworks are built from a collection of objects, so both the design and code of a framework may be reused.

In the language of object-oriented programming, a framework is a set of related classes that can be instantiated (specialized) to build an application. In thinking of a framework as a class library, one must be aware that the flow of control is bi-directional. An operation may well be defined within a library class, but its implementation can lie within the subclass that is in the user's application. In this way, the framework is not just a class library but a design that can be reused to save time and effort. Both the design of function/control structure and the utility of the class libraries are critical to the success of a framework.

These features beyond mere class libraries give frameworks their power, but they also show their potential drawbacks. Like a new computer language, a framework has a learning curve. It requires considerable scrutiny to understand its design and efficient use for developing applications. The most difficult aspect of learning to use frameworks is to understand how they turn "procedural driven programming" on its head. Frameworks follow the principle "Don't call us, we'll call you". Control rests in the framework, with the application providing modules. This is the reverse of the programmer writing MAIN and calling library modules.

Like computer languages, one should be cautious about introducing a new framework unless there is a critical niche to fill. Another analogy might be the physics underlying a Team's scientific applications. When a Team is developing an entirely new framework for problem solving, it should feel nearly as far out on a limb as if it were "building a new physics" to solve problems. If such a Team isn't extremely careful, the danger is that it will become a fringe player. In building frameworks for problem solving, it is important to develop experience using other frameworks to understand their structure. One should examine the available frameworks and try to extend them rather than build a new one. The ESMF project intends to start by examining other community frameworks with the hope that one will prove flexible and extensible enough to provide a basis for the final ESMF. At the very least, existing frameworks should be carefully examined to see how their structure solves as well as creates problems for application developers.

In reviewing a number of frameworks, two features have emerged:

- Good design is not a committee effort.
- Beware of being path breaking in ways that will become routine (i.e., developing a unique solution when a community supported general solution will exist).

The frameworks with clean designs were normally the efforts of a small set of people that grew to become a community effort. The most common failures of frameworks have been to invent new languages for scripting (rather than using C++) or to achieve an important goal such as implementing Web-aware clients before the advent of Java.

In the context of the move to massively parallel machines, compilers have fundamental problems providing the performance that is needed. Code produced by a compiler must be "nearly bulletproof." In a parallel code, this would mean that 99% of the machine's effort would be spent protecting the user by running a variety of run-time condition checking. To achieve performance without extreme effort, we need effective "middleware." Within a framework, the prefabricated building blocks have a lower level of optimized performance. The user is responsible for using the blocks as they were designed, eliminating the vast overhead that would be created by leaving this to the compiler.

A brief annotated bibliography:

1. *Taligent's Guide to Designing Programs; Well-Mannered Object-Oriented Design in C++*, by Taligent, Inc., Addison-Wesley Pub Co; ISBN: 0-201-40888-0.

   Taligent has been absorbed into IBM. Some of their white papers and a bit of their product information can be found at: http://www-4.ibm.com/software/ad/taligent/.

2. *Design Patterns, Elements of Reusable Object-Oriented Software*, Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides, 1995, published by Addison-Wesley, ISBN 0-201-63361-2.

3. ROOT [http://root.cern.ch] is a system for data analysis and data mining that is used extensively by the high energy physics community. It has been adopted in other projects in physics, astronomy, biology, genetics, finance, pharmaceuticals, etc. Two papers for a quick introduction and advocacy are:

   "The Power of Object Oriented Frameworks," F. Rademakers
   ftp://root.cern.ch/root/frameworks.ps.gz

   "ROOT - An Object Oriented Data Analysis Framework," F. Rademakers and R. Brun
   ftp://root.cern.ch/root/laussanne.ps.gz

4. POOMA (Parallel Object-Oriented Methods and Applications) is a framework for "high-performance scientific computation" for applications using uniform meshes and linear algebra based solvers.
   http://www.acl.lanl.gov/pooma/html/tut-07.html

5. Cactus is a name used by two frameworks projects, but the one most relevant here was originally designed for solving Einstein's equations. It is evolving to a general package for PDEs.
   http://www.cactuscode.org

6. Overture targets CFD and combustion in complex moving geometry using structured grids or overlapping structured grids.
   http://www.llnl.gov/casc/Overture/

7. AIPS++ is a framework for astronomical image processing.
   http://aips2.nrao.edu/docs/html/design.html
   It is built on a scripting language GLISH that was originally designed for the Superconducting Supercollider.
   http://aips2.nrao.edu/docs/glish/glish.html
   AIPS++ breaks several of the software engineering rules stated elsewhere in this CAN, primarily because it was designed so early before many of the rules could have been made.

8. Ralph Johnson's frameworks page has a wealth of information.
   http://st-www.cs.uiuc.edu/users/johnson/frameworks.html

9. NASA's Numerical Propulsion System Simulation (NPSS) is an effort by the Glenn Research Center, the aerospace industry, and academia to develop an advanced engineering environment, or integrated collection of software programs, for the analysis and design of aircraft engines and, eventually, space transportation components.
   http://hpcc.lerc.nasa.gov/hpcc2/npssintro.shtml

APPENDIX C
The Earth System Modeling Framework (ESMF)

Focus on interoperability along with performance of Earth System modeling codes

This CAN addresses the need for model interoperation in global Earth system modeling to support Earth science initiatives and their role in global change research. This is a top priority in the Earth Science Strategic Enterprise Plan 1998-2002 (see Appendix F). ESS will put together interested Teams and facilitate their joint specification and construction of a mutually beneficial Earth System Modeling Framework (ESMF). ESS will assist in developing high-performance high-level plug-in applications compatible with the framework and enabling the interoperation of existing community models. The ESMF project is intended to replicate the successes of existing frameworks in other disciplines and thereby fortify standing efforts within the Earth sciences community.

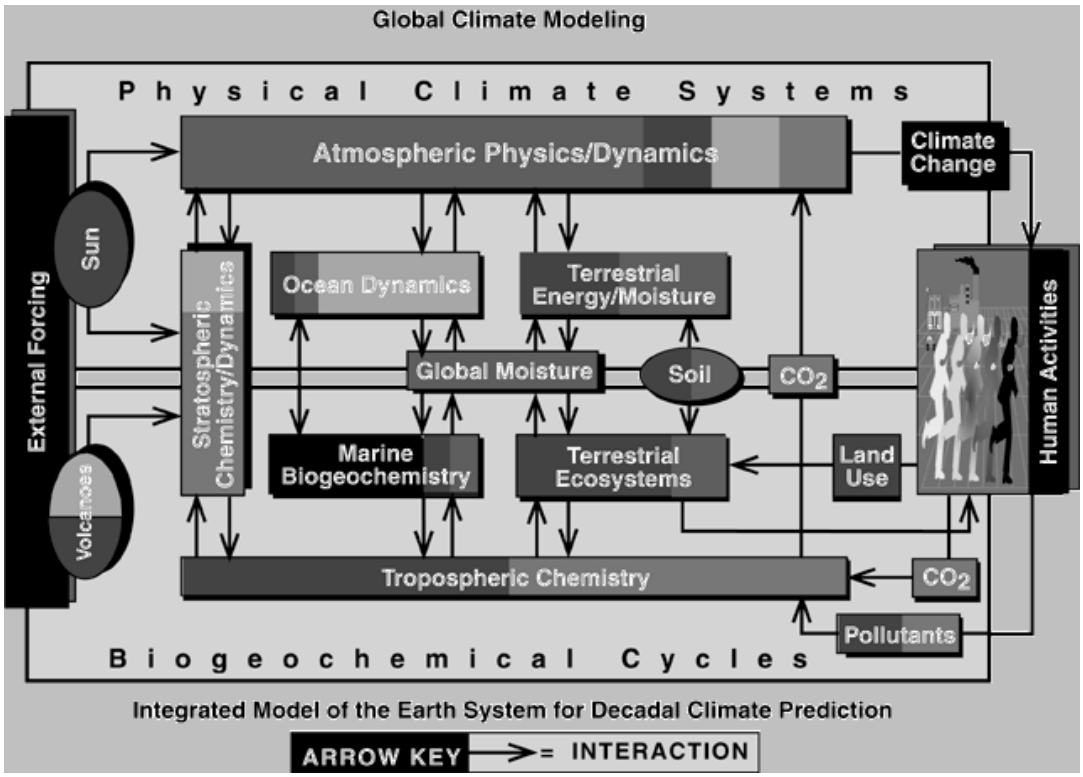

Figure-5: The Earth system and its interactions.
(From page 3 of the Earth Science Strategic Enterprise Plan 1998-2002.)

The Earth Science Enterprise endeavors to understand the total Earth system and the effects of natural and human-induced changes on the global environment. This work takes place in the interdisciplinary field of Earth System Science, that seeks to understand the entire Earth

system on a global scale by describing its component parts, how they interact, and how they may be expected to evolve on all time scales. The challenge to Earth System Science is to develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity. NASA's unique capability for remote sensing of the Earth from space, coupled with *in situ* observation and modeling activities, provides the data needed on global, regional, and sometimes local scales to fuel that understanding. In turn, such data enables science to begin to answer questions such as: *How can we utilize the knowledge of the Sun, Earth, and other planetary bodies to develop predictive environmental, climate, natural disaster, resource identification, and resource management models to help ensure sustainable development and improve the quality of life on Earth?*

Figure-5 shows the Earth system and its interactions, encompassing both natural and human activities. Projecting the future climate requires understanding and quantitatively predicting how the components and interactions will change as a result of natural and human activities. New scientific understanding will enable policymakers, commercial firms, and national, state, and local governments to make sound decisions. Practical applications will lead to synergistic partnerships among public and private sector entities.

ESS has set an objective in Round-3 of facilitating movement of a critical mass of the Earth system modeling community to this common modeling infrastructure. ESS will actively facilitate the joint definition of the ESMF by the U.S. Earth system modeling communities and migration of their codes to this framework. To ensure this, at least three high quality proposals must be selected to participate in the ESMF project. The ESMF project will be a collaborative effort between the ESS Project, the Round-3 Investigator Teams proposing participation in it, and some interested non-funded members of the Earth sciences community. The NASA Headquarters Selection Official will identify membership in an ESMF Science Team to oversee this activity.

ESS is a charged with enabling an array of Earth System modeling efforts. There is a goal of bringing disparate efforts together, not elevating one to a higher status and forcing others into line. When the ESMF is finished, it should enable the creation of the next-generation Earth system models and allow for a variety of plug-in components that interoperate with these models. By itself, it will not be the next-generation model. To achieve these goals, ESS must look across Earth system modeling efforts and provide technical information that is viewed as "objective" or "neutral" with respect to individual modeling efforts. It must also provide leadership in the framework design to ensure a design and toolset that aids, not hinders, the achievement of milestones by participants. To this end, ESS will:

- Provide the services of a software engineering organization, termed the ESMF Integrator, to facilitate and support the development and implementation of the ESMF.
- Maintain distinctions between the ESMF Integrator and the PI Teams to ensure that the Integrator is not perceived as representing the interests of particular Teams over others.

- Appoint a Deputy Project Scientist to chair the ESMF effort who is not associated with any of the Investigator Teams.

The scientific community has been slow to embrace object-oriented programming languages because standard Fortran has proven to provide higher performance. ESS expects the ESMF to be implemented at a high level; low-level performance critical code will probably remain in Fortran or C. Approaches for mixing languages abound. At the very least, it will be necessary to write object-oriented "interface wrappers" around existing portions of software so that standard communication methods can be used. The framework will be constructed using accepted software engineering principles such that:

- Using the framework, *plug-compatibility* is demonstrated with foreign objects and applications codes.
- Shareable class libraries are clearly defined.
- Data are local to major components of the framework; there are no global variables.
- Data are communicated between framework components using the standardized interfaces; there are no multiple entry points within a module.
- Wherever possible, standards and COTS software are employed. For example, Web-aware clients could be implemented in Java, scripting languages could look like C++, and databases could follow CORBA standards.
- High performance will always be required by challenging problems and remains an overarching programmatic goal. The frameworks need to be designed such that model performance is not significantly degraded. A key feature to facilitate enhancement of model performance is designing in flexibility so that new and faster algorithms can be easily tried and adopted.

The Open Source model applies a strong natural selection to software by engaging an entire community in development and testing. The primary manifesto "The Cathedral and the Bazaar" by Eric S. Raymond [http://www.tuxedo.org/~esr/writings/cathedral-bazaar/] highlights several lessons learned that are often echoed by other object-oriented software developers. Those most important to Round-3 efforts are likely to be:

- Beware of excessive top down design.
- Plan to throw one away.
- Good data structures and bad code will take you farther than the reverse.
- Treat your users as co-developers.
- It's not finished until you can't think of anything else to remove.

ESS is not promoting the goal of a giant monolith by insisting on strong software engineering in Round-3.

NASA will provide the services of a software engineering organization, termed the *ESMF Integrator*, during Round-3 to facilitate and support significant technical interaction among the selected Investigator Teams to carry out the ESMF effort. The ESMF Integrator's staff assigned to ESS will be members of the ESS In-house Team, providing software engineering expertise. They will serve as the integrator of the ESMF starting with requirements assessment and option identification and continue through the

specification, design, prototyping, and delivery phases with significant technical contributions from the participating Investigator Teams at each step. The Investigator Teams will be responsible for implementing their codes in conformance with the resulting framework.

During the time interval between the release of the Round-3 CAN and the signing of the cooperative agreements, the ESMF Integrator is tasked to perform several key time critical preparatory activities to support ESS during the CAN negotiations in FY 2000 and jumpstart the work of the ESMF Science Team once cooperative agreements are signed. These activities include:

1) Assessing framework requirements of existing numerical modeling applications that are candidates to interoperate in the ESMF.
2) Comparing and contrasting some existing relevant high-performance frameworks for design principles and lessons learned.
3) Constructing the rationale and weaknesses for a strawman framework that could unite the candidates into a single high-performance framework.
4) Developing definitions of candidate abstract modules for the strawman framework.

To give visibility to these preparatory activities, invite scrutiny by the benefiting community, and support feedback on direction and progress, deliverable items developed by the ESMF Integrator will be placed on the Web at http://esdcd.gsfc.nasa.gov/ESS/frameworks.html, and a method of receiving comments by E-mail will be set up.

APPENDIX D
Testbeds

The ESS Investigator objectives listed in Section 4 are complemented by the following Testbed objectives, that link the Teraflops Scalable Testbed provider, the in-house Commodity Based Testbed staff, and NASA in-house computer and computational scientists:

(i) Enable the Investigators to achieve their code improvement milestones, thereby assisting them to make significant progress in solving their Grand Challenges.

(ii) Explore the role of large clusters of inexpensive commodity PCs in supporting Grand Challenge Investigations and meeting large-scale Agency computing requirements.

(iii) Reveal architectural features that enable/inhibit scalability to multi-teraflops performance for ESS applications.

(iv) Participate in the integration of scalable parallel systems as robust components of the balanced production computing environments needed by the broader ESS community.

In support of these objectives, ESS plans to provide capability computing Testbeds and applications support for Round-3 Investigations as described below.

D.1 Teraflops Scalable Testbed

ESS will arrange for Investigator access to a large parallel computing platform sized to meet the Teams' capability and capacity computing requirements documented by the negotiated milestones in the signed cooperative agreements. Termed the Teraflops Scalable Testbed, this platform will likely be required to sustain one to two hundred gigaflops on benchmarks. The following list shows the groups that will receive access to the Teraflops Scalable Testbed and their percentage of the ESS share:

1) ESS Grand Challenge Investigators selected through this CAN 55%
2) ESS researchers selected through a Guest Investigator program (described in Appendix E) 20%
3) Experimental use by Investigators selected by the NASA HPCC Computational Aerospace Sciences (CAS) Project 15%
4) Support activities of the ESS In-house Team staff 5%
5) Experimental use by NASA fellowship awardees 3%
6) Evaluation experiments organized by the ESS Evaluation Team 2%

The Teraflops Scalable Testbed will be shared with other NASA projects that also require high-end performance, allowing ESS Investigators access to a significantly larger Testbed for milestone or capability demonstration runs, for an estimated 5% of wall clock time. Investigator access to the larger Testbed will be by arrangement with the provider.

The Testbed provider will be required to supply strong applications support to assist Round-3 Investigations to achieve negotiated code improvement milestones F and G (see Sections 1-3 of Appendix A) when these milestones have been negotiated with quantified performance metrics. The testbed provider will be required to provide support to assure that at least 50% of these milestones are met. It is anticipated that the testbed provider will develop long-term strategies with the Investigators to support code restructuring and optimizations geared toward Investigator milestone achievement.

Negotiations with Round-3 Investigators may be completed before the Teraflops Scalable Testbed is available. ESS has made provision to retain access full time to 272 processors of the 1,360-processor CRAY T3E at GSFC for initial Round-3 Investigator code baselining and milestone achievement. Occasional access will be available by arrangement to larger partitions of the system.

D.2 Commodity Based Testbed

The ability to construct powerful cluster computers entirely from commodity components offers a new dynamic in the evolution of large systems, allowing leading-edge mass market consumer products to be deployed on the computer room floor to support the scientific community as soon as they are released for public sale. Round-3 Investigators are encouraged but not required to make significant use of PC clusters (see Sections 4 and 5 of Appendix A) including:

1) Construction of a PC cluster at their home sites for code development, and
2) Achievement of code improvement milestones on the ESS provided Commodity Based Testbed.

Since 1995, ESS has integrated four generations of Linux-based commodity clusters and plans to continue this approach throughout the time period of Round-3 with a system termed the Commodity Based Testbed, sized to meet Round-3 Teams' computing requirements as documented by specific negotiated optional milestones in the signed cooperative agreements. Various shortcomings in the Linux system software environment impede the movement of clusters to the production computing floor. ESS plans to release a separate solicitation to address some of these shortcomings after all cooperative agreements are signed and the Round-3 Science Team has formed and helped ESS to prioritize its needs.

D.3 Testbed Availability, Guidelines and Network Access

The Teraflops Scalable Testbed is intended to be available 24 hours a day, 7 days a week except for scheduled preventive maintenance and system upgrades (estimated 95 percent availability). User support will be available Monday through Friday, 9AM to 5PM Eastern Time, and additionally on an arranged basis; operator support will also be available. The user support function, to be provided by the Testbed provider, will include training, consultation, and assistance with problems and help with planning and review of algorithm implementation to assure effective Testbed utilization. On-line and near-line storage space will be made available for each Investigator. The uniqueness of individual systems and limited experience with hardware and software failure can cause uncertainties in projecting overall reliability.

ESS Testbed computers will be accessible through vBNS, NASA Integrated Services Network (NISN), and the NASA Research and Education Network (NREN), as well as through other NGI networks such as the other "JETnets" (e.g., Abilene, ESnet, DREN) or the DARPA SuperNet (e.g., NTON, ATDnet/MONET, HSCC, BOSSnet, OnRamp). High-speed network backbone paths running at a minimum rate of 155 Mbps will connect the various NASA HPCC testbed sites. Testbed connections via NGI/SuperNets may permit testbed access at 622 Mbps or higher rates.

D.4 Other Computing Facilities

Investigator Teams are expected to use the Teraflops Scalable Testbed and Commodity Based Testbed to achieve their milestones. In addition, ESS will provide access to other high-performance computing testbed research facilities to the extent resources permit. User support needs to be provided by those facilities. Investigator Teams are encouraged to use other scalable parallel systems available to them where such use will yield enhanced code portability and understanding of performance from comparative analyses.

APPENDIX E
Summary of ESS Round-3 Activities

The ESS Project is a component of the NASA High Performance Computing and Communications (HPCC) Program, that is a critical element of the Federal Program in Computing, Information and Communication. Sources of information on both the Federal and NASA programs are listed in Appendix F.

The goals of the NASA HPCC Program are to accelerate the development, application, and transfer of high-performance computing and computer communications technologies to meet the engineering and science needs of the U.S. aerospace, Earth and space sciences, spaceborne research, and education communities and to accelerate the distribution of these technologies to the American public. This work is carried out to narrow the computing gap that now exists between current computing and data management capabilities and the requirements of scientists, engineers, and their missions, thereby addressing strategically important computational problems that are beyond current capabilities. ESS is one of five projects in the NASA HPCC Program, the others being Computational Aerospace Sciences (CAS), Remote Exploration and Experimentation (REE), the NASA Research and Education Network (NREN), and Learning Technologies (LT).

The ESS Round-3 effort is a comprehensive set of complementary activities coordinated by the ESS Project Office to bring together capabilities and expertise in support of the Earth, space, life, and microgravity science goals. The left column below names the activity, and the right column states where it is described in this CAN:

- Round-3 Grand Challenge Investigations	Section 6
- Teraflops Scalable Testbed with support staff for performance optimization and operations	Appendix D
- Commodity Based Testbed, with support staff for development, performance optimization, and operations	Appendix D
- Earth System Modeling Framework Integrator	Appendix C
- Solicitations for High Performance Plug-ins	Appendix E.1
- Guest Investigator Program	Appendix E.2
- Guest Investigator Facility	Appendix E.3
- Performance Evaluation staff	Appendix E.4
- GSFC and JPL Center-based staff developing applications middleware and plug-in software	Section 2
- NASA-based research in visualization, mass storage, and networking	Appendix A.4 (b, c, d)
- Visualization task order services	Section 2
- Basic research awards program in system software	Appendix D.2

E.1 Solicitation for High Performance Plug-ins

ESS work has tended towards the "grandest" challenges, but excellent, cutting-edge applications development may be done in more "component" areas. The various framework communities that ESS Round-3 Investigations will represent, including that of the Earth System Modeling Framework, are likely to find that their science would substantively benefit from the availability of specific high-performance software components compatible with their framework. Software components will be provided by groups within the various framework science communities but many could come from other groups, such as numericists, expert in their field, who may not typically be involved in support of the branch of science represented by the benefiting framework community.

Once some Investigator Teams have achieved milestone "H – agree on design policy for interoperability and community delivery," ESS plans to enlist those Teams in prioritizing the specific needs of their communities and then issue a CAN separate from the Round-3 CAN for 'plug-in' software components. Those Teams will be expected to assist ESS in evaluating proposals and to provide their frameworks to awardees. Plug-in cooperative agreements will be signed for specific software milestones to be completed, and each awardee will need to have a provider/customer relationship with one or more members of a Round-3 framework community. Awards will typically be valued at $50,000 - $100,000 per year and extend over two years. Between 10 and 20 such awards are envisioned to be active at any time. ESS envisions follow-on 'plug-in' solicitations if significant benefit to science can be shown, and has reserved several million dollars in FY 2001 through FY 2004 to fund 'plug-in' awards. The high-performance plug-ins solicitation is not part of this CAN and will be announced at http://esdcd.gsfc.nasa.gov/ESS/.

E.2 Guest Investigator Program

Beginning in FY 2001, ESS will solicit proposals every 6 months to give scientists from the broader ESS community who receive NASA funding but are not funded under this CAN access to the Teraflops Scalable Testbed. Such access will assist them in preparing to use scalable parallel systems as they become common in production computing facilities. Twenty percent of the Teraflops Scalable Testbed will be made available for use by Guest Investigators. A limited amount of training and support will be provided for these users. The instructions and schedule for Guest Investigator proposal submissions will be posted at http://esdcd.gsfc.nasa.gov/ESS/crayt3e/account/access.policy.html

E.3 Guest Investigator Facility

The ESS Project operates a Guest Investigator facility at GSFC to house members of Investigator Teams when they visit for periods of time to work closely with the Testbed provider and NASA in-house computer and computational scientists.

E.4 Performance Evaluation

ESS considers code performance evaluation to be an essential part of Round-3 and will provide a technical evaluation staff of computer scientists specializing in computer system evaluation as part of the ESS In-house Team. They will assist the Investigator Teams in characterizing their applications codes and in carrying out performance and scaling measurements on the Testbeds. Performance evaluation will focus on the large-scale Grand Challenge codes and their interactions with the parallel testbed systems. Evaluation will include the static and dynamic characteristics of the codes that affect performance and interoperability as well as characteristics of the testbeds that affect performance and usability. An objective of the evaluation work will be identification and understanding of the critical success factors for the selected Grand Challenge Investigations. Expected output of the evaluation work is direct feedback to the Teams as well as analytic articles in professional and trade journals.

The goal of the evaluation effort is to understand the characteristics and interactions among the computational platform, the application code, and the underlying model. This understanding will help ESS predict and deliver the computational resources required to meet the goals of research scientists and flight missions. The in-house Evaluation Team proposes a layered approach to this problem. The approach will involve the collaboration of vendors, In-house Team, and PIs, focusing on different points where the layers are integrated into the framework being used.

Each Team will identify a point of contact to the in-house Evaluation Team. This person will be responsible for explaining the software engineering scheme employed in the application and will assist in correlating the key scientific contributions of the application with modules within the framework being used. At the highest level, the PI Teams are responsible for identifying scientific progress and, through the contact person, will assist the in-house team in identifying code improvements that are responsible for that progress. At the lowest level, the In-house Team will work with the PI Team to obtain scaling curves for the entire application and for each of the components within the framework using conventional performance monitoring tools as provided by the Testbed vendors. In between, the In-house Team will work with the PI Team to correlate the computational load specified by the application code with the performance of the Testbed while executing the application. The primary tool will be software instrumentation that will measure individual modules and perhaps more importantly measure the interaction among the modules in the framework. The In-house Team will instrument key modules and the interfaces between modules and will work with the point of contact to track the evolving application code. The software instrumentation will be the primary tool used to understand the relationship between performance improvements as measured by the scientific milestones and more traditional measures of computer performance. This understanding is expected to provide a credible foundation for predictions of resource requirements for future Grand Challenge Investigations and performance predictions for these codes running on anticipated architectures.

E.5 Summary – Round-2 of the ESS Project

In Round-2 (FY 1996-2000), nine Grand Challenge Investigator Teams and a Testbed vendor were selected to work in close collaboration to achieve negotiated end-to-end performance goals on specified Investigator codes.

Both the Round-2 Investigators and the Testbed vendor were acquired through a single Cooperative Agreement Notice (CAN-21425/041) structured to use milestone payments to provide an incentive for strong collaboration between the Testbed vendor and the Investigators to meet aggressive ESS performance milestones of 10, 50, and 100 gigaflops sustained (or 200-fold improvement over baseline) on Investigator codes. The CAN was released in May 1995, proposals were received in August 1995, and a full peer review was carried out for the Investigator proposals. All 10 cooperative agreements between GSFC and Investigator institutions, worth $12.6 million in total, had been signed by the fall of 1996. All Cooperative Agreements are worded identically and an example can be found at http://esdcd.gsfc.nasa.gov/ESS/can.invagree.html. The example contains all sections except the last section "18. Milestone Schedule and Payments" that contains the milestones and that is unique to each agreement. The cooperative agreement between GSFC and SGI/Cray was worth $13.2 million. All cooperative agreements had lifetimes of approximately three years. Descriptions of the nine Round-2 ESS Grand Challenge Investigations can be found at http://esdcd.gsfc.nasa.gov/ESS/grand.st2.html.

The negotiated milestones focused Round-2 Teams to achieve a 200-fold improvement in computational capability over the Project's 1992 baseline. All codes that achieved performance milestones were required to be documented and released to the science community on the Web through the National HPCC Software Exchange (NHSE) [http://www.nhse.org]. All payments under the Round-2 Cooperative Agreements were tied to achievement of milestones. A table of all Investigator and Testbed vendor milestones is found at http://esdcd.gsfc.nasa.gov/ESS/can.milestones.html; these were Level-3 milestones in the NASA HPCC Program. There are 117 negotiated milestones worth a total of $25,803,000. The cooperative agreement with SGI/Cray resulted in placement of a large scalable parallel Testbed (512-processor CRAY T3E) at GSFC, primarily to support the research needs of the Round-2 Investigators but also to assist in transitioning the broader NASA science community to parallel computing and to support research of the HPCC CAS Project. An additional 512 more processors were added to this Testbed in 1998 by the Earth Science Enterprise to support the production computing requirements of the NASA Seasonal to Interannual Prediction Project (NSIPP).

As of February 2000, eight ESS Round-2 Grand Challenge Teams had achieved 50 gigaflops sustained performance on their code(s) as negotiated, eight had submitted documented versions of these codes to the NHSE, eight had achieved 100 gigaflops sustained, and five had submitted versions of these codes to the NHSE.

APPENDIX F
World Wide Web References to Project Information

• Address technical questions regarding this CAN to:

Mr. Omar Spaulding
Code YF
NASA Headquarters
Washington, DC 20546-0001
Telephone: 202-358-0777
FAX: 202-358-2891
E-mail: ospauldi@hq.nasa.gov

• Address administrative or procurement related questions regarding this CAN to:

Mr. Cosimo Lucchese, Contract Specialist
Code 219
NASA Goddard Space Flight Center
Greenbelt, MD 20771
Telephone: 301-614-5584
FAX: 301-614-5619
E-mail: Cosimo.Lucchese.1@gsfc.nasa.gov

• Letters of intent are to be submitted via a Web form found at:

http://props.oss.hq.nasa.gov

• The NASA Grant and Cooperative Agreement Handbook can be accessed at:

http://genesis.gsfc.nasa.gov/grants/grants.htm#GrantsForms

• NASA Policy Directives (NPD):

http://nodis.hq.nasa.gov/Library/processes.html/

• The Federal Acquisition Regulations (FAR) can be accessed at:

http://www.arnet.gov/far/

• History of the ESS Project and electronic copies of this CAN:

http://esdcd.gsfc.nasa.gov/ESS/

• ESS Round-2 Investigator Cooperative Agreement:

http://esdcd.gsfc.nasa.gov/ESS/can.invagree.html

• Draft ESS Round-3 Investigator Cooperative Agreement:

http://esdcd.gsfc.nasa.gov/ES+S/CAN2000/CAN.html

• ESS Software Repository:

http://esdcd.gsfc.nasa.gov/RIB/repositories/ESS/catalog/index.html

• Preparatory activities for the Earth System Modeling Framework are posted at:

http://esdcd.gsfc.nasa.gov/ESS/frameworks.html

• Solicitation for high-performance plug-in applications will be announced at:

http://esdcd.gsfc.nasa.gov/ESS/

• Schedule for submission of Guest Investigator applications:

http://esdcd.gsfc.nasa.gov/ESS/crayt3e/account/access.policy.html

• Information about the NASA HPCC Program, including annual reports:
http://hpcc.arc.nasa.gov/

• The NASA Strategic Plan:
http://www.hq.nasa.gov/office/nsp/

• The Earth Science Strategic Enterprise Plan 1998-2002:
http://www.earth.nasa.gov/visions/stratplan/index.html

• The Space Science Enterprise Strategic Plan:
http://spacescience.nasa.gov/strategy/1997/

• The Office of Life and Microgravity Sciences and Applications Strategic Plan:
http://www.hq.nasa.gov/office/olmsa/lifesci/index.htm

• The NASA Implementation Plan for Education 1999 - 2003:
http://education.nasa.gov/implan/exec.html

• The Earth Science Enterprise Education Strategy (March 1996):
http://www.earth.nasa.gov/education/edstratplan/index.html

• Partners in Education, a Strategy for Integrating Education and Public Outreach into NASA's Space Science Programs:
http://spacescience.nasa.gov/edu/educov.htm

• Office of Space Science Education Implementation Plan:
http://spacescience.nasa.gov/edu/imp_plan.htm

• The OSS Explanatory Guide for Education Public Outreach Evaluation Criteria:
http://www.hq.nasa.gov/office/oss/education/guide.html

• Obtain information about the Federal program in Computing, Information and Communications (CIC), including the documents listed below, from the:

National Coordination Office for Computing,
Information, and Communications
Suite 690
4201 Wilson Boulevard
Arlington, VA 22230

http://www.ccic.gov/
Phone: 703-306-4722
FAX: 703-306-4727
E-mail: nco@ccic.gov

- President's Information Technology Advisory Committee Report to the President "Information Technology Research: Investing in Our Future", February 1999
http://www.ccic.gov/ac/report/

- FY 2000 Blue Book, April 1999
"High Performance Computing and Communications: Information Technology Frontiers for a New Millennium"
http://www.ccic.gov/pubs/blue00/contents.html

- FY 2000 Implementation Plan, June 1999
"Information Technology for the Twenty-First Century: A Bold Investment in America's Future"
http://www.ccic.gov/pubs/it2-ip/

• Report from the "NSF Workshop On a Software Research Program For the 21st Century" October 1998:
http://www.cs.umd.edu/projects/SoftEng/tame/nsfw98

APPENDIX G
Guidance for Grand Challenge Investigation Proposals

G.1 Peer Review Process

A full peer review will be carried out under the supervision of the Peer Review Committee, that will ensure impartiality. This committee is chaired by the Associate Director for Technology in the Program Planning and Development Division in the Earth Science Enterprise at NASA Headquarters. The peer review will be based on Evaluation Criteria I through III stated in Section G.7. Scientists who are knowledgeable and experienced in the relevant areas of science, as well as technologists who are familiar with software engineering, parallel computational techniques, supercomputer architectures and systems, visualization, and networking, will be chosen to review the proposals. Proposals will be sent out to two sets of mail reviewers and be rated on their scientific and technology qualities. Peer review panels in discipline sciences and technology will be convened using a subset of the mail reviewers. Investigator Team proposals will be assigned to the appropriate discipline science panel based on proposed science thrust. The technology panel will review all proposals. The discipline science panels will evaluate proposals in the two Evaluation Criteria areas I and III. The technology panel will evaluate proposals in the two Evaluation Criteria areas II and III. The members of the technology panel will join the discipline science panels to merge the evaluations. Evaluated proposals will then be forwarded to the Headquarters Selection Committee, which will ensure breadth, diversity, and relevance to NASA in the final selections. The Selection Committee is chaired by the Head of the Research Division in the Earth Science Enterprise at NASA Headquarters and populated by designated program managers from among the Earth Science Enterprise, Space Science Enterprise, Office of Life and Microgravity Sciences and Applications, and the Office of Aerospace Technology. The Selection Committee will then make its recommendations to the Selection Official, who will select Teams for negotiations. The Selection Official will strive for program balance for maximal impact. ESS will carry out the negotiations and GSFC will sign cooperative agreements with those Teams that successfully complete the negotiation process. In the event of any conflict between this Appendix G and the provisions of the NASA Grant and Cooperative Agreement Handbook, the CAN controls.

G.2 Letter of Intent to Submit a Proposal

To determine the areas of expertise required of peer reviewers in advance, and to increase the efficiency of proposal management, it is requested that all Grand Challenge Investigator proposers electronically submit a Letter of Intent by Wednesday, October 18, 2000. To do so, use the Web-based form at:

http://props.oss.hq.nasa.gov

Proposers without access to the Web or who experience difficulty in using this site should contact Ms. Deborah Tripp by E-mail at dtripp@mail.hq.nasa.gov or by phone at 202-479-9030 x263.

Letters of Intent will include the following information:

Name, address, and telephone number of the Principal Investigator.

Name, address, and telephone number of any Co-Investigators.

Tentative title of the Investigation to be proposed.

Brief abstract of the Investigation to be proposed.

Key words describing proposed work as might be used by a technical abstracting service.

G.3 Data Rights

In order to rapidly transfer the parallel algorithm and tool technology developed by Investigator Teams to the broader community, NASA will require such data to be delivered to the ESS Software Repository (see Appendix F) with unlimited rights in connection with the appropriate Rights in Data provision included in the resulting cooperative agreements. However, if the software is planned to be commercialized, then the Investigator Team(s) developing such a product may benefit from a delay in implementing the above submission requirement, provided that cost-sharing is proposed. If commercialization is planned, then Investigators must include a detailed cost sharing section in their proposal and specify the proposed period of exclusive use of the software prior to delivery. For educational institutions and nonprofit organizations, the data rights provision at section 1260.29 of the NASA Grant and Cooperative Agreement Handbook applies; for commercial organizations, the data rights provision at section 1274.905 applies. Both recognize a period of exclusivity for protection of data produced under cost sharing arrangements.

G.4 Proposal Format, Content, and Page Limit

Proposals submitted by prospective Investigators in response to this CAN should be in the following order:

	Page Length (max.)
i. Research Proposal Cover Page and Proposal Summary (see Section G.8)	Printout of electronic submission
ii. Table of Contents	1 page
iii. Science/Technology/Management Section This section should be written with the realization that reviews are being conducted by both discipline and technology panels	15 pages (including all figures)
iv. Software Engineering Plan	3 pages
v. References (for sections iii. and iv.)	3 pages

vi. Biographical Sketches	maximum 1 page each PI and Co-I
vii. Milestones/Schedule/Cost (see Appendix A) (a traditional budget page should not be submitted)	3 pages
viii. Endorsement letters from other institutions	1 page per institution
ix. Education and Public Outreach Addendum	2 pages

Proposals must be written concisely in English. The proposal must be prepared on 8.5 x 11 inch paper (A4 size is also acceptable) and must use a font size and line spacing of at least 12 points, with 1-inch margins and with pages in the order listed above. Smaller font size may be used for figures and captions only. Appendices are not permitted. Double-sided printing is encouraged. Note that reviewers will only read proposals submitted in the correct format, to the maximum page limits listed above. Color images are allowed; however, a color image must be included in each proposal copy. NASA will not be responsible for reproducing color materials. Do not include videotapes, CD-ROMs, or other electronic media; they will not be viewed.

When completing the prefatory forms, please note that for proposals in response to this CAN, NASA recognizes only <u>one</u> Principal Investigator (PI) for each proposal. Other Investigators are designated Co-Investigators (Co-Is), even if their proposal and science responsibilities are comparable to that of the PI.

The proposer's sponsoring institution must endorse each proposal. Only properly endorsed proposals are acceptable. The Cover Page contains space for this endorsement by an institutional representative authorized to legally bind the institution to perform the proposed effort. If substantial collaborations with other institutions are involved, then the responsible officials from those institutions should submit letters of endorsement. Each endorsement letter should indicate agreement with the nature of the collaboration detailed in the proposal, that should be identified by title and date of submission. All endorsement letters should refer to the Earth and Space Sciences Project of the High Performance Computing and Communications Program.

To facilitate the recycling of shredded proposals after review, proposals should be submitted on plain, white paper only (except for color images). This precludes the use of cardboard stock, plastic covers, colored paper, and binders such as three-ring, GBC, spiral, plastic strips, etc.

G.5 Proposal Instructions

Most proposal items listed in Section G.4 are self-explanatory. Items iii, iv, vii, and ix are described below in more detail.

The **science component** of item iii must include the following:

- List the objectives of the proposed Investigation. Proposed work should show a connection to NASA mission data products in an appropriate manner. State explicitly the importance and relevance of scalable parallel computing technology to enable the proposed science and justify value of the proposed work in terms of new science results or mission support expected to result.
- Explain the scientific rationale. Identify a broader scientific community that will be served by the ESS technology program, provide a specific plan for delivering new capabilities to this community.

The **technology component** of item iii must include the following:

- Describe the method for interoperability that you anticipate implementing. If you are using an existing framework explain the extensions you anticipate making to meet your requirements. If you are designing a new framework explain the method for determining requirements and the method for designing and testing the framework. In any case explain how your method will enable interoperability and support the incorporation of new capabilities by your community. Explain how you will gain community buy-in and how you will deliver your product to the community and evaluate its acceptance and impact.
- Identify the model(s), analysis, or data processing application(s) that will be developed to meet the code improvement milestone(s). The ESS Project understands and expects that in order to achieve such large improvements, major recoding of the application programs may be required. Describe the approach to be taken and identify efforts required to redesign/restructure the codes to take full advantage of high-performance parallel execution. Provide quantified metrics and milestone achievement criteria. The handling of large data sets will be one of the key technology components of Round-3. Describe specific work to be undertaken in this area.
- Due to the aggressive performance demands of the ESS Project, this CAN is intended for scientists currently using parallel systems. Show prior parallel computing experience in the scientific domain being proposed. At a minimum, submit evidence that the Investigator Team has successfully developed parallel applications in the proposed scientific domain that run on at least 128 processors concurrently with at least a 50% efficiency of scaling for a fixed problem size; include a plot of the speedup curve. List the platforms on which these application programs have been run and corresponding application and code performance measurements.

The **management component** of item iii must include the following:

- Present a management plan. Identify the PI and Co-Is. The teaming arrangement proposed for an Investigator Team should be complete and balanced, containing all necessary backgrounds and skills in the Team to carry out the project including the physical and computational/computer scientists and the software engineers.
- Identify the technical background and skills on your Team to enable the implementation of software frameworks for your particular application.

The **software engineering plan section** (item iv) must include the following:

- In a distinct section, present your software engineering plan including the process you will use to develop software requirements, develop the software, conduct the testing, and complete the final product.

The **milestones/schedule/cost** section (item vii) must include the following:

- Include a list of proposed milestones in a format similar to that shown in Section 6 of Appendix A. Meaningful milestones spread throughout the 3-year award period must be proposed. They will serve as a plan for code interoperation, code improvement, and administrative reporting. Proposed milestones must include the 11 Required Investigator Milestones as described in Sections 1-3 of Appendix A and up to two optional milestones as described in Sections 4-5 of Appendix A. The total values of the code interoperation, code improvement, and administrative milestones should fall into the percentage ratios indicated in Figure-1. It is the Investigator's responsibility to structure the value of each milestone so that funds sufficient for the achievement of the subsequent milestone are paid out and available for Investigator use. Milestones and payments will be finalized during negotiations prior to award. An advance payment to an Investigator will only be made upon the achievement and validation of the prior milestone. Milestones will not be paid out of order.
- List additional contributions to this research activity (i.e., institutional support for hardware procurements, partial funding of postdoctoral positions, etc.). Non-NASA resources should be verified by a letter of commitment signed by an authorized representative of the organization(s). Non-NASA funding sources should indicate the resources contributed and any conditions concerning the use of resources.
- Describe type and level of resource sharing in the proposed research, if that research will produce commercializable software. (This is not required of proposers who agree to submit resulting algorithms and tools to the ESS Software Repository with unlimited rights in connection with the appropriate Rights in Data provision included in the resulting cooperative agreements.)

The optional **Education and Public Outreach Addendum** (item ix) should include:

- Clear and succinct statement of the goals and objectives of the E/PO effort.
- Identification of the audience and educational needs being addressed and why this is important.
- Description of how scientists will be involved as E/PO partners, and how E/PO implementation will be managed and coordinated.
- Statement of the proposed E/PO milestone along with a plan and schedule for activities and/or products.
- Description of the approach to evaluate the effectiveness of the overall effort.
- Description of general dissemination strategies for any resulting educational products.
- Table summarizing activities, partners/leads, estimated costs and timing.

G.6 Proposal Quantity and Mailing Address

Twenty copies of each Investigator proposal should be submitted so as to arrive at the following address by 4:30 PM (Eastern Daylight Time) on Monday, November 20, 2000. Proposers must either deliver their proposal by U.S. Postal Service Mail or hand deliver (includes the use of a commercial delivery service such as United Parcel Service, Federal Express, DHL, and Purolator).

U.S. Mail
CAN-00-OES-01
500 E Street SW
Suite 200
Washington, DC 20024

Commercial or overnight delivery service (8:00 AM to 4:30 PM, Monday through Friday, except Government Holidays)
CAN-00-OES-01
500 E Street SW
Suite 200
Washington, DC 20024
Phone: 202-479-9030

Regardless of the delivery method chosen, the proposal must be closed and sealed as if for mailing. Late proposals will not be reviewed unless it is deemed to be in the best interest of the government. Acknowledgement of receipt of proposal will be provided via email to the PI.

G.7 Evaluation Criteria

Below are the evaluation criteria for proposals submitted to this CAN. There are three principal elements to be considered: scientific quality of proposal and Team, technical quality of proposal and Team, and cost. The first two elements are equally weighted and significantly more important than the third element. All elements will be evaluated.

I. Scientific quality of proposal and Team

Evaluation of the proposal's scientific quality includes consideration of the following factors; no order of importance is implied:

a. Scientific merit and breadth of proposed Grand Challenge application and its relevance to Earth, space, life, or microgravity science goals and objectives;

b. Incorporation of NASA data to understand phenomena or to test and evaluate the models being developed;

c. Scientific and computational expertise of the Team proposed, including experience with large computational problems; past support of a broader user community in their field; and

d. Strength of proposal to build community capabilities through software frameworks or other proposed techniques; value of proposed software deliverables to the science community including the extent of technology transfer and training of eventual users; the potential for benefits and insights from participation in a multidisciplinary environment.

II. Technical quality of proposal and Team

Evaluation of the proposal's technical quality includes consideration of the following factors; no order of importance is implied:

a. Feasibility of accomplishing code improvement goals with proposed resources, based on scaling projections derived from applications executed on current parallel computing systems;

b. Strength of software engineering plan; clarity of process to document and evaluate software requirements and design, to enable interoperability, and to deliver new capabilities to a broader community;

c. Software engineering expertise of the Team proposed to advance community software efforts, experience with user communities, expertise in creating interoperable code;

d. Feasibility of the approach to enable code interoperability and deliver new capabilities to a broader community; possibility for product impact in other disciplines and its potential for commercialization; and

e. Presence and quality of optional milestones.

III. Cost

Evaluation of the proposal's cost includes consideration of the following factors, listed in descending order of importance:

a. The reasonableness and realism of the cost of the proposed effort (total value of all milestones) and the relationship of the proposed cost to available funds; and

b. Level of proposed cost-sharing, if any (required in proposals from commercial firms).

G.8 Required Proposal Forms

A Cover Page and Proposal Summary must be part of the proposal, but will not be counted against the page limit. It must be signed by the Principal Investigator and an official by title of the investigator's organization who is authorized to commit the organization. This authorizing signature also certifies that the proposing institution has read and is in compliance with the three required certifications printed in full in section 9 of Appendix G; therefore, certifications do not need to be submitted separately.

The Cover Page and Proposal Summary must be submitted electronically to the Web site located at http://props.oss.hq.nasa.gov. An outline of the information requested is included below. A hard copy version of this Cover must be printed in time to acquire signatures and include with the original hard copy of the proposal for delivery according to the schedule provided in section 12 of this CAN.

Proposers are advised that they must not reformat this Cover after it is printed, as important NASA-required documentation may be lost. Proposers without access to the Web or who experience difficulty in using this site may contact dtripp@mail.hq.nasa.gov for assistance. Please note that submission of the electronic Cover does not satisfy the deadline for proposal submission.

It is NASA's intent to enter the Summaries of all investigations selected for award by its various programs into a publically accessible database. Therefore, the Summary should not contain any proprietary or confidential information that the submitter wishes to protect from public disclosure.

The "Research Proposal Cover " requests:

- Proposal Title
- Principal Investigator's Signature and Date
- Typed Name and Title of Principal Investigator
- Principal Investigator's Telephone Number with Area Code
- Principal Investigator's E-mail address
- Name of Institution
- Authorizing Institutional Official's Signature and Date
- Authorizing Institutional Official's Typed Name and Title
- Authorizing Institutional Official's Telephone Number with Area Code
- Institutional Address, including Postal Code and Country

The "Proposal Summary – Part I" requests:

- Key words describing proposed work as might be used by a technical abstracting service
- Abstract: (200 to 300 words)
- Co-Investigator's Full Name(s), Institution(s), and E-mail address(es)

- Budget Summary by Federal Government Fiscal Year: (total value of milestones expected to be achieved in these timeframes) in FY 2001 (10/00 - 9/01), FY 2002 (10/01 - 9/02), FY 2003 (10/02 - 9/03), and FY 2004 (10/03 – 9/04).

The "Proposal Summary – Part II" states:

- In order to evaluate the reasonableness of the costs associated with proposal milestones, please fill in the table provided. See the example that follows these instructions.

- Instructions:
  - Identification: List in this column all individuals identified by name in the proposal. Also list as TBD other categories of individuals who will be used in this effort. Use one line per job category (see next field).
  - Job Category: Enter a title which describes the professional level of named person or other workforce, such as Professor, Asst. Professor, Sr. Research Staff, Programmer, Post-Doc, Grad Student, etc.
  - FTE: Enter approximate portion of time, in Full Time Equivalents (FTE), to be spent by the named person or workforce category on the proposed work ***over the lifetime*** of the award.
  - Fully Burdened Total Cost: Total cost ***over all years*** for this person or category, in Thousands.

- Example:

Identification	Job Category	FTE	Fully Burdened Total Cost
1. John Doe	Prof	1.2	$225K
2. Jane Air	Prof	.75	$84K
3. Sam Smith	Asst Prof	3.0	$315K
4. TBD	Post-Doc	6.0	$450K
5. TBD	Programr	2.4	$200K
6. TBD	Grad Stud.	4.5	$200K
7. TBD	Clerical	.5	$20K
8.			

The "Proposal Summary – Part III – Framework for Interoperability" states:

- Mark, with an X, all items that apply and provide descriptive text as called for. Please limit your response to a single page.

____ Proposing Team is involved with an existing community framework to be used/enhanced during Round-3. Please identify framework and its participating community. [A block for entering text follows.]

____ Proposing Team will be involved in bringing about a community framework during Round-3. Please identify benefiting community and describe planned process for achieving agreement by community participants. [A block for entering text follows.]

____ Proposing Team requests to be part of the Earth System Modeling Framework (ESMF) Science Team.

G.9 Required Certifications

The three certifications are on the following three pages:

Certification Regarding Lobbying
for Contracts, Grants, Loans, and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form - LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certificate shall be subject to a civil penalty of not less than $10,000, and not more than $100,000 for each such failure.

_____ _____

Signature Date

_____

Name and Title of Authorized Representative

_____

Organization Name

Certification Regarding
Debarment, Suspension, and Other Responsibility Matters
Primary Covered Transactions

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participant's responsibilities. The regulations were published as Part VII of the May 26, 1988 Federal Register (pages 19160 - 19211). Copies of the regulation may be obtained by contacting the U.S. Department of Education, Grants and Contracts Service, 400 Maryland Avenue, S.W. (Room 3633 GSA Regional Office Building No. 3), Washington, DC. 20202-4725, telephone (202) 732-2505.

(1) The prospective primary participant certifies to the best of its knowledge and belief, that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;

(b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or Local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State, or Local) with commission of any of the offenses enumerated in paragraph (1)(b) of this certification; and

(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State, or Local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

Organization Name	PR/Award Number or Project Name

Name and Title of Authorized Representative

Signature	Date

ED Form GCS-008 (REV.12/88)

Assurance of Compliance with the National Aeronautics
and Space Administration Regulations Pursuant to
Nondiscrimination in Federally Assisted Programs

The _____,
(*Institution, corporation, firm, or other organization on whose behalf this assurance is signed, hereinafter called "Applicant")*

HEREBY AGREES THAT it will comply with Title VI of the Civil Rights Act of 1964 (P.L. 88-352), Title IX of the Education Amendments of 1962 (20 U.S.C. 1680 et seq.), Section 504 of the Rehabilitation Act of 1973, as amended (29 U.S.C. 794), and the Age Discrimination Act of 1975 (42 U.S.C. 16101 et seq), and all requirements imposed by or pursuant to the Regulation of the National Aeronautics and Space Administration (14 CFR Part 1250) (hereinafter call "NASA") issued pursuant to these laws, to the end that in accordance with these laws and regulations, no person in the United States shall, on the basis of race, color, national origin, sex, handicapped condition, or age be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant receives federal financial assistance from NASA; and HEREBY GIVE ASSURANCE THAT it will immediately take any measure necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of federal financial assistance extended to the Applicant by NASA, this assurance shall obligate the Applicant, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided, this assurance shall obligate the Applicant for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant for the period during which the federal financial assistance is extended to it by NASA.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all federal grants, loans, contracts, property, discounts, or other federal financial assistance extended after the date hereof to the Applicant by NASA, including installment payments after such date on account of applications for federal financial assistance which were approved before such date. The Applicant recognized and agrees that such federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign on behalf of the Applicant.

Dated:
_____

Applicant: _____

By:_____
(*President, Chairman of Board, or Comparable Authorized Person)*

_____
_

_____
_
(Applicant's mailing address)

NASA FORM 1206 AUG 97 PREVIOUS EDITIONS ARE OBSOLETE

APPENDIX H
Preproposal Conference

The Pre-Proposal Conference will be held on October 2, 2000. The conference will begin at 9:00 a.m. Please contact Peggy Danielson at 202-479-9030 ext.218 to register. You may also send an email to: pdanielson@nasaprs.com.

Hotel: Sheraton Crystal City
1800 Jefferson Davis Highway
Arlington, VA 22202

Telephone: (703) 486-1111
Fax: (703) 769-3970

APPENDIX I
Definition of Terms

- *capability computing* ..... Access to a significant collection of computing resources in a coordinated fashion within a finite window of time. Requires the utilization of over half of the system's CPU, memory, disk, and/or I/O resources to support individual applications. In the extreme, capability jobs are so memory or CPU-intensive that the dedication of a large resource for days or weeks is required. May involve interactive analysis and visualization of data that is too large to be moved to or displayed on the users' desktops.

- *capacity-computing* ..... Access to a large number of compute cycles over some period of time. These cycles need only be delivered in relatively small quanta. Typically, this means that the application can be decomposed into a large number of runs, each requiring a modest number of processors. A common metric is in units of throughput or the amount of specific work that can be accomplished per unit time.

- *Cooperative Agreement* ... A financial assistance instrument used to stimulate or support activities for authorized purposes and in which the Government participates substantially in the performance of the effort.

- *Earth System Modeling Framework* ... The intended outcome of a collaborative effort among the ESS Project and the Round-3 Investigator Teams representing the U.S. Earth system modeling communities to jointly define and develop a common software modeling infrastructure to assist community collaboration.

- *ESS applications* ..... ESS is used to designate the portion of the NASA HPCC project that is issuing this CAN. In the context of "ESS applications", this should be viewed to include Life and Microgravity Sciences as well as Earth and Space Sciences.

- *ESS In-house Team* ..... Project staff at GSFC and JPL who support the Project and the Investigator Teams to achieve Project milestones. Collaboration between Investigators and the In-house Team is encouraged.

- *framework* ..... A set of cooperating classes that makes up a reusable design for a specific class of software. A framework provides

architectural guidance by partitioning the design into abstract classes and defining their responsibilities and collaborations. A developer customizes the framework to a particular application by subclassing and composing instances of framework classes.

- *Grand Challenge* ..... A fundamental problem in science or engineering with potentially broad economic, political, and/or scientific impact, that may be advanced through the application of high-performance computing resources.

- *operational computing* ..... Access to a very stable computing resource supported by a variety of software, hardware and staff services focused on the user. Operational systems may run old vendor releases of system software to maintain stability and compatibility. They may be dedicated full-time or part-time to specific work. Software development is not performed on operational platforms.

- *production computing* ..... Access to stable computing resources supported by a variety of software, hardware and staff services focused on the user. Production systems stay current with the vendor release of system software. Software development is performed on production platforms.

APPENDIX J
Abbreviation and Acronym Guide

3D	Three-dimensional
5D	Five-dimensional
AMR	Adaptive Mesh Refinement
ARC	Ames Research Center, Moffett Field, CA
ATDnet	Advanced Technology Demonstration network
CAN	Cooperative Agreement Notice
CAS	Computational Aerospace Sciences Project
CAVE	Cave Automatic Virtual Environment
CFD	Computational Fluid Dynamics
CIC	Federal program in Computing, Information and Communications
Co-I	Co-Investigator
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off The Shelf
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DOE	Department of Energy
DREN	Defense Research and Engineering Network
ESMF	Earth System Modeling Framework
ESnet	Energy Science Network
ESS	Earth and Space Sciences Project
FAR	Federal Acquisition Regulations
FEMA	Federal Emergency Management Agency
FTE	Full Time Equivalent
GB	Gigabyte
GI	Guest Investigator
Gigaflops	10^9 (1 Billion) Floating Point Operations per Second
GSFC	Goddard Space Flight Center, Greenbelt, MD
GUI	Graphical User Interface
HBCUs	Historically Black Colleges and Universities
HDTV	High Definition Television
HEDS	Human Exploration and Development of Space Enterprise
HPCC	High Performance Computing and Communications Program
HPREN	High Performance Research and Education Networks
IBM	International Business Machines
I/O	Data Input and Output
JPL	Jet Propulsion Laboratory, Pasadena, CA
LAIR	Lucid Animated Interactive Realm (the personal CAVE)
LT	Learning Technologies Project
MB	Megabyte
MONET	Multiwavelength Optical Network
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration

NCCS	NASA Center for Computational Sciences
NFS	NASA FAR Supplement
NGI	Next Generation Internet
NHSE	National HPCC Software Exchange
NISN	NASA Integrated Services Network

NPD	NASA Policy Directive
NREN	HPCC NASA Research and Education Network Project
NSF	National Science Foundation
NSIPP	NASA Seasonal to Interannual Prediction Project
NTON	National Transparent Optical Network
PC	Personal computer
PDE	Partial Differential Equations
PI	Principal Investigator
PITAC	President's Information Technology Advisory Committee
POOMA	Parallel Object-Oriented Methods and Applications
QoS	Quality of Service
REE	Remote Exploration and Experimentation Project
SAR	Synthetic Aperture Radar
SC02	Supercomputing Conference in 2002
SGI	Silicon Graphics, Inc.
SVS	Scientific Visualization Studio at GSFC
Teraflops	10^{12} (1 Trillion) Floating Point Operations per Second
URL	Universal Resource Locator
U.S.	United States
vBNS	very high-speed Backbone Network Service
WAN	Wide Area Network
WDM	Wave Division Multiplex